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G. Evans, R. Baumgardner, J. Bumgarner, P. Finkelstein, J. Knoll, B. Martin (EPA) A. Sykes, D.Wagoner, C.Decker (RTI)	

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Short-term field studies were conducted in each of three major metropolitan areas which were selected on the basis of the number, density and size of perchloroethylene emission sources as well as the proximity of such sources to centers of high population density. Dry cleaning, a ubiquitous activity scattered throughout any metropolitan area, increases in volume proportionately with population density. Hence, New York City, with the greatest population density in the U.S., was selected as a study area. Metropolitan Houston was chosen primarily because the Diamond Shamrock plant, located in suburban Deer Park, is one of the largest perchloroethylene producers in the nation. Finally, metropolitan Detroit was included because of the number of metal degreasing operations located in the area.

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MEASUREMENT OF PERCHLOROETHYLENE IN AMBIENT AIR

by

G. F. Evans, R. E. Baumgardner, J. E. Bumgarner
P. L. Finkelstein, J. E. Knoll and B. E. Martin
Environmental Monitoring and Support Laboratory
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

and

A. L. Sykes, D. E. Wagoner and C. E. Decker
Research Triangle Institute
Research Triangle Park, North Carolina 27709

ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring and Support Laboratory, Research Triangle Park, North Carolina, has the responsibility for: assessment of environmental monitoring technology and systems; implementation of agency-wide quality assurance programs for air pollution measurement systems; and supplying technical support to other groups in the Agency including the Office of Air, Noise and Radiation, the Office of Toxic Substances and the Office of Enforcement.

This study was conducted at the request of the Office of Toxic Substances for use in health risk assessment. A system for measurement of perchloroethylene in ambient air was developed and evaluated. Field monitoring was conducted and ambient perchloroethylene concentrations reported for three metropolitan areas. Precision and accuracy of the reported data were characterized through implementation of a quality assurance program.

Thomas R. Hauser
Director
Environmental Monitoring and
Support Laboratory

ABSTRACT

Perchloroethylene (i.e., tetrachloroethylene) is an organic solvent widely used in dry cleaning and industrial metal degreasing operations. In March 1978, in response to a carcinogenic risk study by the National Cancer Institute, the U.S. Environmental Protection Agency undertook a program to measure perchloroethylene concentrations in ambient air. This program was initiated by the Office of Toxic Substances and supported by the Office of Air Quality Planning and Standards. The research was conducted by the Environmental Monitoring and Support Laboratory with contractual assistance from the Research Triangle Institute.

Short-term field studies were conducted in three major metropolitan areas, selected on the basis of the number, density, and size of perchloroethylene emission sources as well as the proximity of these sources to centers of high population density. Dry cleaning, a ubiquitous activity scattered throughout any metropolitan area, increases in volume proportionately with population density. Hence, New York City, with the greatest population density in the U.S., was selected as a study area. Metropolitan Houston was chosen primarily because the Diamond Shamrock plant, located in suburban Deer Park, is one of the largest perchloroethylene producers in the nation. Finally, metropolitan Detroit was included because of the number of metal degreasing operations located in the area.

Ten monitoring sites were established within each of the three metropolitan areas. Most site locations were selected to represent the air quality to which the population is typically exposed (i.e., commercial and residential areas); however, a few source-specific sites were included in the study design. A combination of existing sites operated by state and local agencies and new sites established expressly for this study was utilized. Twenty-four hour integrated samples were collected on activated charcoal at each site for a period of 10 consecutive days. In addition, meteorological data were obtained at one of the monitoring sites in each city and a comprehensive quality assurance plan was maintained throughout the program.

Observed perchloroethylene concentrations ranged from 0.2 to 10.6 ppb in New York City, from below detectable (<0.1) to 4.5 ppb in Houston, and from below detectable to 2.2 ppb in Detroit. The higher concentrations tended to occur where source strengths were greatest and significant day-of-week variations were apparent.

This report covers a period from March 1, 1978, through February 28, 1979, and work was completed as of February 28, 1979.

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In addition, the EPA is indebted to the following agencies for their substantial contributions to the design and conduct of the field monitoring activities: the New York State Department of Environmental Conservation, the New York City Department of Air Resources, the Texas Air Control Board, the City of Houston Department of Public Health, and the Wayne County (Michigan) Health Department.

SECTION I

INTRODUCTION

In March 1978, the Environmental Monitoring and Support Laboratory (EMSL) at Research Triangle Park (RTP), North Carolina, undertook a research program to investigate perchloroethylene (PERC) levels in the ambient air of our nation's urban areas. This research was initiated by the Office of Toxic Substances (OTS) and was partially funded by the Office of Air Quality Planning and Standards (OAQPS) in support of concurrent health risk assessment and regulatory activities. Planning and management for this program were accomplished through a task force comprised of representatives from each component of EMSL with active participation and technical review provided by OTS, OAQPS, and Research Triangle Institute (RTI).

Although some grab-sample measurements of PERC (i.e., tetrachloroethylene) in ambient air have been previously reported in the literature (1), a well-defined methodology for sampling and analysis at the anticipated ambient levels (sub-ppb) was not available at the inception of this program. Therefore, RTI developed methodology for the collection and quantitative analysis of PERC in 24-hour integrated samples over the concentration range of 0.10 to 10.00 ppb. A method based on adsorption by activated charcoal, desorption by carbon disulfide (CS_2)/methanol, separation by gas chromatography and detection by electron capture detector (ECD) was developed and tested under both laboratory and field operating conditions. A description of the method is given in Appendix A.

EMSL designed and conducted a field monitoring program, incorporating such factors as the nature, size, and density of emission sources within major population centers and the likely impact of prevailing meteorological conditions. Short-term monitoring studies were conducted in the greater metropolitan areas of New York City, Houston, and Detroit. Within each study area, 10 PERC monitoring locations and a single meteorological monitoring location were established with the assistance of personnel from the appropriate EPA regional office and state and local agencies.

SECTION 2

SUMMARY AND CONCLUSIONS

Ambient PERC concentrations observed in the field monitoring program are summarized in Table 1. All samples collected in New York City exceeded the detection limit of the measurement method (0.10 ppb), half exceeded 1 ppb, and a single observation was slightly greater than 10 ppb. In the Houston and Detroit areas, by contrast, about 90 percent of all measurements were less than 1 ppb. Nearly half (46 percent) of the Houston samples and 12 percent of the Detroit samples fell below the detection limit.

TABLE 1. SUMMARY OF AMBIENT PERCHLOROETHYLENE CONCENTRATIONS

City	NO.	Cumulative Frequency (%) less than:			Concentration (ppb)		
		0.10 ppb*	1.00 ppb	10.00 ppb	Min	Max	Median
New York, NY	95	0	49.5	98.9	0.16	10.61	1.00
Houston, TX	96	45.8	90.6	100.0	<0.10	4.52	0.11
Detroit, MI	100	12.0	90.0	100.0	<0.10	2.16	0.35

*Detection Limit

The data suggest that ambient PERC concentrations in urban areas are generally proportional to population density (the populations per square mile of Houston and Detroit are approximately 11 percent and 47 percent, respectively, of that in New York City (2)). Maximum concentrations occur in the vicinity of point sources of PERC emissions such as industrial-scale dry cleaning plants and PERC manufacturing facilities. A distinct day-of-week concentration pattern exists with the higher concentrations occurring midweek, tapering off to a minimum on Sunday. Ambient levels of PERC increase during periods of atmospheric stagnation caused by light winds and limited vertical mixing. Background concentrations occurring at nonurban and upwind locations appear to be minimal (<0.10 ppb).

The precision of the analytical method employed, expressed as a coefficient of variation for the total measurement system (including sample collection, handling, and preparation) is approximately 16 percent. The accuracy (i.e., mean recovery efficiency) of the measurement method is estimated to be 70 percent.

SECTION 3

EXPERIMENTAL PROCEDURES

The intent of the field monitoring program for PERC was to establish a reliable data base reflecting the ambient concentrations of this organic solvent to which people are routinely exposed in urban environments. Since dry cleaning establishments account for most emissions (1), traces of PERC would be expected in the atmosphere of almost any populated area. Other emission sources include industrial degreasing operations and, of course, PERC manufacturing facilities.

Program resources permitted the conduct of a short-term monitoring effort within each of three geographic localities. Assuming that the intensity of dry cleaning activity is proportional to population density, New York City (which has the highest population density in the nation (2)) would be expected to exhibit relatively high ambient PERC concentrations. Indeed, preliminary studies (1,3) confirm this expectation. Metropolitan New York, therefore, was selected for inclusion in the field monitoring program. The greater Houston area was chosen primarily because the Diamond Shamrock plant (located in suburban Deer Park) is one of the largest PERC producers in the nation. Finally, metropolitan Detroit was included on the basis of the number of metal degreasing operations located in the area.

Meetings were held with personnel from the appropriate EPA Regional Office and state and local agencies in each of these cities for the purpose of designing a monitoring study. A network consisting of 10 PERC sampling sites and a single meteorological monitoring station was established within each metropolitan area. Field sampling was conducted by EMSL's Monitoring and Analytical Chemistry Branch (MACB) for 10 consecutive days within each of the study areas. Exposed samples were delivered to RTI whose personnel, operating under Contract No. 68-02-2722, performed and reported the chemical analyses, including internal quality control. An external quality assurance plan was developed by EMSL's Quality Assurance Branch (QAB) and maintained throughout the study period. Data assessment and project leadership were provided by EMSL's Statistical and Technical Analysis Branch (STAB).

SELECTION OF SAMPLING SITES

New York

The ten sampling locations selected in the New York metropolitan area are listed in Table 2 and displayed on an area map in Figure 1. As indicated

Table 2. SAMPLING SITE LOCATIONS IN NEW YORK, NEW YORK

Site	Address (Borough)	Class	Type	Elevation (M)
1. Battery Park Fireboat Sta.	1 West Side Elevated (M)	N	B/C	6
2. Police Dept.	Pitt & Broome St. (M)	N	R/C	8
3. Queensboro Bridge	59th & 2nd Ave. (M)	N	R/C	8
4. Central Park Arsenal	64th & 5th Ave. (M)	S	B/C	14
5. City College of NY	W. 140th & Covenant (M)	S	R/C	23
6. Greenpoint Treatment Plant	Greenpoint & Humbolt (B)	S	I/C	6
7. Bowery Bay Treatment Plant	Berrian Blvd & 41st (Q)	C	I/R	20
8. Brooklyn Public Library	Flatbush & Grand Army (B)	S	R/C	18
9. Boro Hall	Queens Blvd & 82 (Q)	C	R/C	15
10. Coney Is. Treatment Plant	Knapp St. & Ave. Z (B)	N	B/R	9

Borough Code

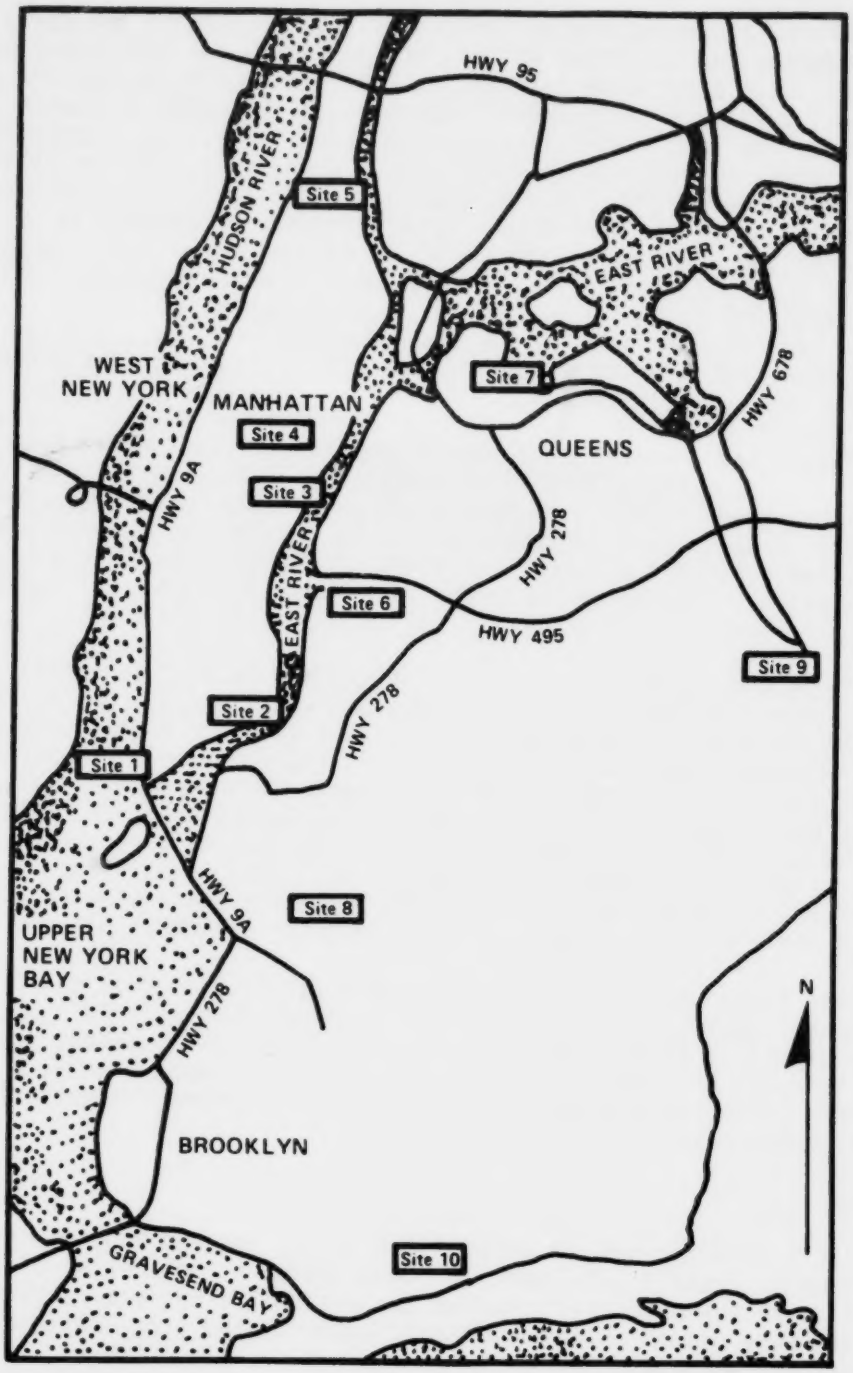
M: Manhattan
Q: Queens
B: Brooklyn

Class Code

S: Existing State Site
C: Existing City Site
N: New Site

Type Code

I: Industrial
C: Commercial
R: Residential
B: Background



NOTE: Meteorology monitored at Site 6

Figure 1. Sampling site locations in New York, New York.

in the table, a combination of existing sites operated by the state and local agencies and new sites established expressly for this study was employed. Five sites were selected on the island of Manhattan and an additional five were distributed throughout the boroughs of Queens and Brooklyn to the east. The sites were selected to provide a variety of expected local emission and meteorological conditions. In the table, each site is assigned a primary and secondary classification according to the characteristics of the surrounding area (industrial, commercial, residential, or background). Because of the high-rise nature of New York's urban structure, all monitoring sites were located on building rooftops at the approximate elevations shown in the table. In an effort to obtain representative samples, care was taken to select sites not dominated by taller buildings nearby and to position each sampler away from any potentially interfering structure on the rooftop.

Sites 2 and 3 are located in a predominantly residential area characterized by clusters of high-rise apartment buildings and would, therefore, be expected to possess a high density of relatively small sources of PERC emissions in the form of neighborhood (i.e., commercial) dry cleaning establishments (William Seitz, Neighborhood Cleaners Assn., N.Y.C., personal communication). The other Manhattan sites represent a mix of residential, commercial, and background conditions.

Site 6 and, to a lesser extent, Site 7 are located in heavily industrial sections of the Borough of Queens and would be expected to reflect emissions from metal cleaning operations and industrial-scale dry cleaning plants (although much fewer in number, one industrial dry cleaner emits many times the quantity of PERC emitted by a typical commercial establishment, so that the former may be considered a point source while the latter falls into the category of an area source (4)). An industrial-scale cleaner, the Klink plant, is known (Hugh Tipping, NYC Dept. of Air Resources, personal communication) to be located just a few blocks to the southwest of Site 6. Sites 8 and 9 are in residential and commercial neighborhoods.

Site 6 was chosen to monitor the meteorological conditions prevailing during the sampling period because it is situated roughly in the center of the geographic area of interest and offers a relatively unobstructed exposure. Because southwesterly winds were considered most likely, Sites 1 and 10 were expected to provide measures of the background concentrations of PERC in ambient air.

Houston

The monitoring network established in the greater Houston area is described in Table 3 and Figure 2. Once again, a combination of agency-operated and new sites was required to provide the desired regional coverage. Samplers were placed on the rooftops of one- or two-story buildings, on trailers, or at ground level.

Sites 1 through 6 are situated in predominantly residential and/or commercial neighborhoods within the Houston city limits. However, an industrial dry cleaning plant, Mechanics' Uniform Supply Co., was known

Table 3. SAMPLING SITE LOCATIONS IN HOUSTON, TEXAS

Site	Address (City)	Class	Type	Elevation (M)
1. Region VI Lab	6608 Hornwood St. (H)	R	C/R	4
2. Fire Station	Aberdeen & Stella Link (H)	C	R/C	6
3. Fire Station	Alabama & Cummins (H)	C	R/C	6
4. Water Treatment Plant	San Jacinto & Rothwell (H)	C	C/I	Ground
5. Fire Station	Kress & Lyons (H)	C	R/C	6
6. Port Houston Terminal	Clinton & Mississippi (H)	C	I/R	Ground
7. Universal Steel	Sheldon & DeZavalla (C)	N	I/R	Ground
8. Pasadena Health Dept.	Shaw & Charles (P)	C	R/C	9
9. Deer Park City Hall	Center & Helgra (D)	C	I/R	5
10. State Trailer	4510 Aldine Mail Rd.	S	B/R	4

City Code

H: Houston
P: Pasadena
D: Deer Park
C: Channel View

Class Code

S: Existing State Site
C: Existing City Site
R: Existing Regional Site
N: New Site

Type Code

I: Industrial
C: Commercial
R: Residential
B: Background

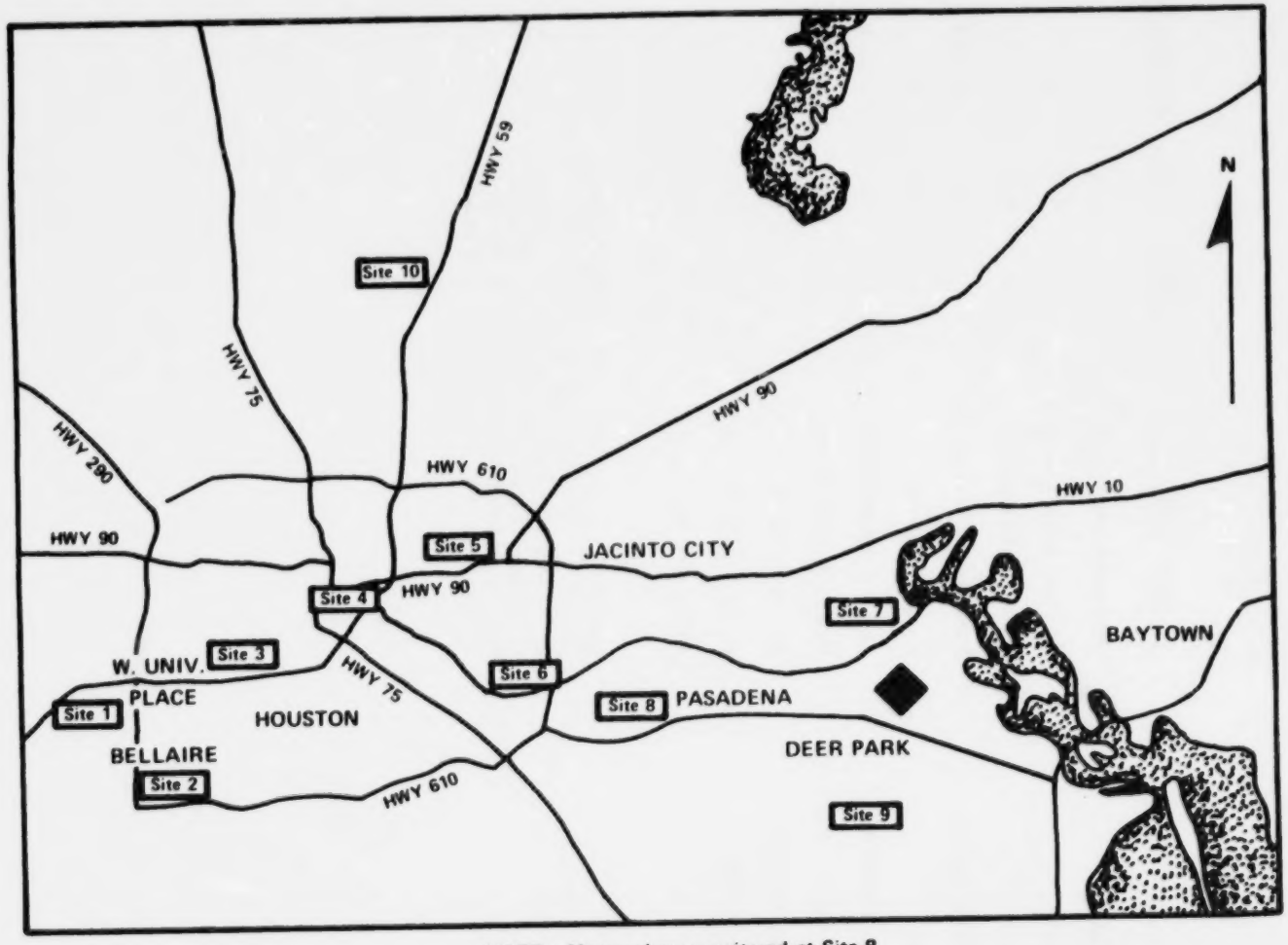


Figure 2. Sampling site locations in Houston, Texas.

(Vernon Jennings, City of Houston Dept. of Public Health, personal communication) to be operating at a location just two blocks east of Site 3 during the sampling period in September 1978. The plant has since moved to another location.

Sites 7 and 9 were used to bracket the Diamond Shamrock plant, located along the ship canal in Deer Park. This plant is one of the largest PERC production facilities in the country. Site 7 was established on the premises of an industrial compound north of the plant site, while the neighborhood immediately surrounding Site 9 to the south is residential and commercial.

Site 8 was chosen to serve as the meteorological monitoring station for the study. Since either southeasterly or northeasterly winds are expected in the Houston area during the fall, this site also provided a further downwind point from which to assess the impact of emissions from the Diamond Shamrock facility. Site 10 is located in a residential area north of the city and was included to serve as a reference point for background measurements during northerly winds.

Detroit

Table 4 and Figure 3 depict the sampling locations selected in the Detroit metropolitan area. The Wayne County Health Department operates a comprehensive air quality monitoring network in and around Detroit, and it was possible to utilize 10 of these existing sites in the PERC monitoring program. All sampler placements were made on rooftops of monitoring trailers.

Sites 1 through 5 are distributed within the older, more densely populated and industrial section of the city. Estimates of perchloroethylene usage by source (Dr. Peter Warner, Wayne County Health Dept., personal communication) suggest that the higher PERC levels in ambient air would occur in this section of the city. The five other sites are scattered throughout less populated areas lying to the west and south of the downtown section. Site 3 was chosen for meteorological monitoring because, being within a city park and openly exposed, it was likely to be representative of the entire area under study.

COLLECTION AND HANDLING OF FIELD SAMPLES

Field samples were collected by MACB/EMSL/EPA for 10 consecutive days within each metropolitan study area. An attempt was made to schedule sampling in the New York area to coincide with the annual peak in dry cleaning volume occurring in the early fall. Sampling was conducted in 1978 from 8/18 to 8/27 in New York, from 9/16 to 9/25 in Houston, and from 10/27 to 11/5 in Detroit.

In each study, 24-hour integrated PERC samples were collected in duplicate on charcoal cartridges at the 10 preselected monitoring locations.

Table 4. SAMPLING SITE LOCATIONS IN DETROIT, MICHIGAN

Site	Address (City)	Class	Type	Elevation (M)
1. High School Grounds	Linhurst & Strasburg (Dt)	W	I/C	4
2. Grade School Grounds	Goethe & Lemay (Dt)	W	C/R	4
3. Highland Park	Davison & Oakland (Dt)	W	B/I	4
4. City Playground	Stanton & Marquette (Dt)	W	C/R	4
5. Detroit Public Library	Fort & Rademacher (Dt)	W	C/R	4
6. Stoepel Park	Auburn & Schoolcraft (Dt)	W	B/R	4
7. U. of Michigan	Hubbard & Evergreen (Db)	W	R/C	4
8. Newburgh Substation	Cherry Hill & Lotz	W	B/R	4
9. City Playground	Genessee & Chestnut (RR)	W	C/R	4
10. Madonna College	Levan & Martin (L)	W	R/I	4

City Code

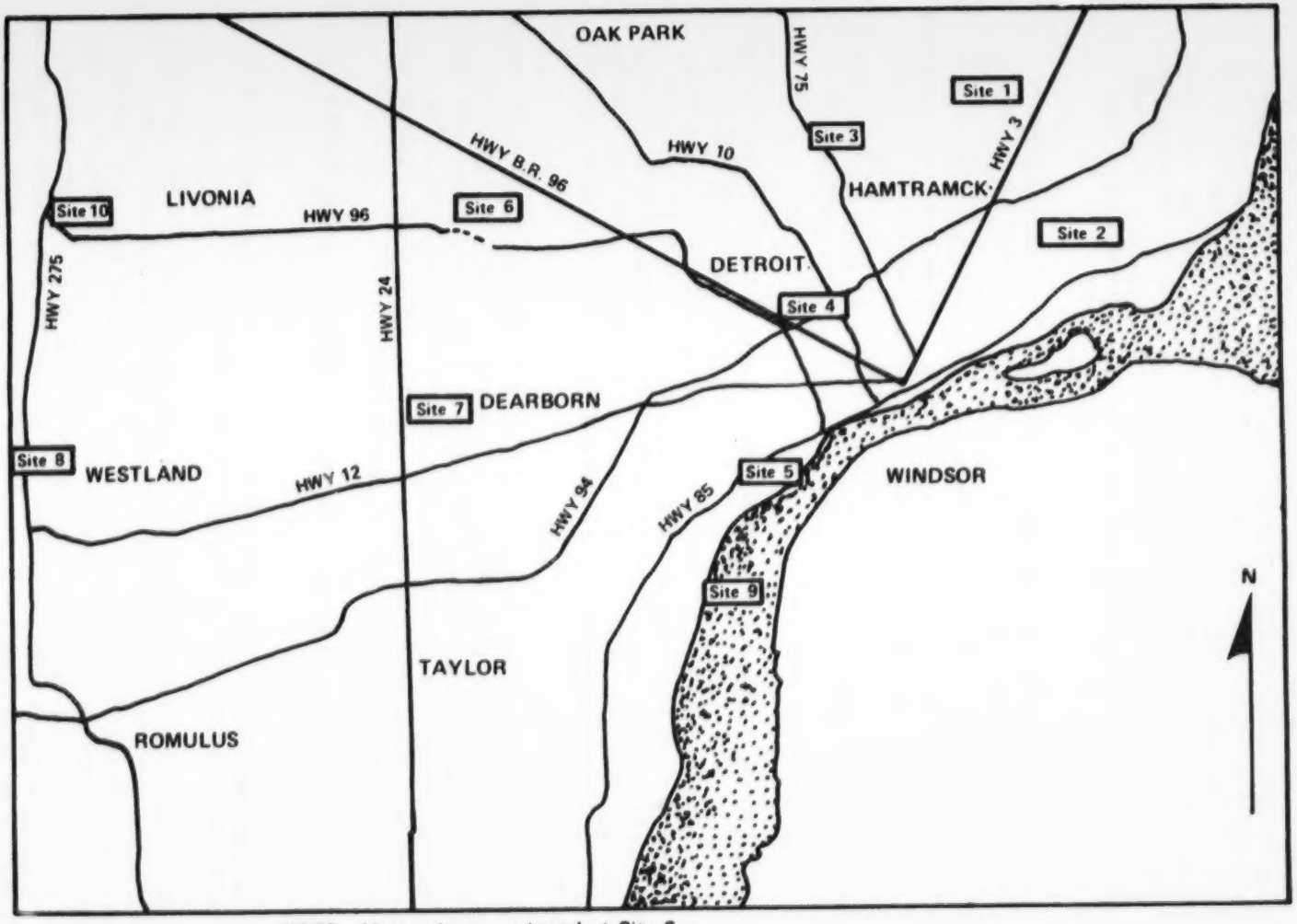
Dt: Detroit
Db: Dearborn
RR: River Rouge
L: Livonia

Class Code

W: Existing Wayne Co. Sites

Type Code

I: Industrial
C: Commercial
R: Residential
B: Background



NOTE: Meteorology monitored at Site 3.

Figure 3. Sampling site locations in Detroit, Michigan.

Special handling procedures were used to assure non-contamination of the sampling cartridges before and after sampling. The PERC cartridges used were manufactured by SKC, Inc., and each cartridge contained a front and back section of charcoal. The cartridges supplied were all from lot #107 and contained 100 mg and 50 mg of charcoal in the front and back sections, respectively. The sampling flow rate was set at 250 cm^3/min and measured before, during, and after sampling. The flow through the cartridges was controlled by micro-needle valves, and the flow rate was measured using a calibrated rotameter.

A field sampler capable of collecting duplicate samples was used to collect the 24-hour integrated samples of PERC on the charcoal cartridges. Each sampler contained a pump, 2 micrometer needle valves, an elapsed time meter, and a 7-day timer. The pump was capable of maintaining 250 cm^3/min flow through two cartridges with an excess of 20 in. Hg vacuum. Two samplers were required at each site to allow automatic start and end at 12 midnight. A diagram of the sampler components appears in Figure 4. A calibrated rotameter was used to set the flow through the cartridge and to check the flow rate during and after sampling. The rotameter was calibrated both prior to and after field use.

After sampling, the cartridges were kept cool by freezer storage prior to shipment to RTP. The cartridges were shipped in a Trans Temp shipping container capable of maintaining sub-freezing temperature during shipment. The cartridges are supplied with tapered glass seals. Prior to use, the taper was broken. After sampling, the cartridges were sealed with plastic caps, placed in a culture tube, and sealed with a Teflon-lined cap. Also, the culture tubes were wrapped with aluminum foil to reduce sample loss due to irradiation by light.

A MRI meteorological (met) station was used to collect wind speed, wind direction, and temperature at a representative site in each of the study areas. The unit was assembled and oriented with true north. Each day the met system was checked for proper orientation and time synchronization, and the chart was dated and time recorded. At the end of each phase of the study, the data were reduced to hourly observations.

The following instructions were followed by MACB personnel in the conduct of each field study:

1. Place two samplers at each preselected site in such a manner as to insure the collection of a representative sample.

2. Prior to placing the cartridge on the sampler, break off the cartridge ends and place the charcoal tubes on the sampler which will operate the next day. Note: The charcoal tubes must be placed onto the sampler with the larger section of charcoal facing down. Adjust the flow rate to 250 cm^3/min and set timer to come on at midnight. Record sample flow rate, elapsed time meter reading, and vacuum pump operating vacuum on the Daily Check Sheet. If the vacuum reading falls below 20 psig, check the system for leaks and, if necessary, replace the pump.

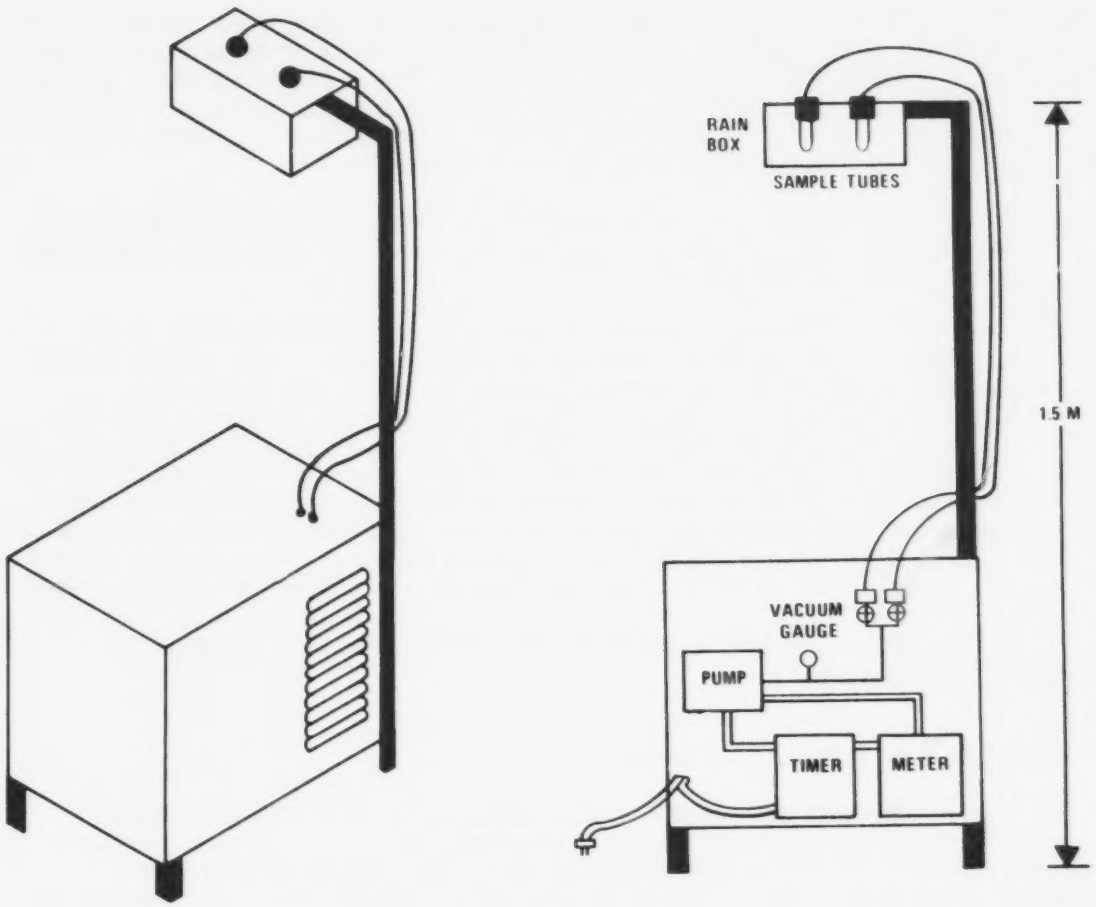


Figure 4. Diagram of perchloroethylene sampler.

3. Return to the site the next day. Check the flow rate through the cartridges that are collecting a sample for this 24-hour period and record on data sheet. Perform step 2 on the sampler to operate for the next 24-hour period.

4. Check the flow rate through the cartridges that operated the previous 24 hours and record on data sheet. Remove the cartridges and cap the ends immediately with the caps provided. Place the cartridges in the Teflon-capped culture tubes. Wrap the culture tube with aluminum foil. Identify tube with sample tube number, site number, and date. Place exposed cartridges in a freezer until return to RTP.

5. After 2 or 3 days of sample collection, the exposed cartridges should be removed from the storage freezer and placed in the Trans Temp shipping container for return to RTP.

6. The exposed cartridges packed in the shipping container are to be shipped Federal Express. Because a 1-day delivery time of the field samples is required, no cartridges are to be shipped on Friday, Saturday, or Sunday. Any cartridges (exposed or unexposed) remaining after the 10 days of sampling should returned by the field personnel to RTP using the shipping containers. The exposed cartridges must remain refrigerated until receipt. If the return trip occurs over a weekend, the cartridges should be stored in a suitable freezer until they can be delivered to RTP on the following Monday morning. Upon arrival at RTP, all samples are to be labeled and immediately placed in storage at 0°C.

A sample Daily Check Sheet with specific instructions appears in Appendix A (Table A-1).

LABORATORY ANALYTICAL PROCEDURES

Laboratory analysis for PERC was performed by RTI on the samples collected in each of the three field studies. Upon receipt, all samples were labeled and immediately stored at 0°C. Storage experiments have demonstrated that PERC is stable on charcoal tubes for at least 1 month at 0°C, and all field samples were analyzed within 3 weeks of receipt.

Each 150 mg charcoal tube was scored with a triangular file and broken above the glass wool and retainer. The glass wool and retainer were discarded and the charcoal was poured into a H.P. mini-vial. One mℓ of 25 percent CS_2/methanol was added to the vial, which was then crimp sealed with a Teflon-lined cap. The vials were ultrasonicated five minutes and allowed to stand for 1 hour. One μℓ of standard or sample was injected into the gas chromatograph (GC). All injections were made using the solvent flush technique. Two μℓ of methanol were first drawn into the syringe after washing in a two-stage cleaning procedure. A 1-μℓ space was left between the solvent and the sample. Reagent and charcoal tube blanks were run and considered in preparation of the calibration curve.

The analysis was performed on a Perkin Elmer 3920 GC equipped with a nickel 63 ECD. The column utilized was a 6.35 mm o.d. glass column, 2 mm i.d. x 1.8 M packed with 0.1 percent SP-1000 on Carbopack C 60-80 mesh supplied by Supelco, Inc. A 5 percent methane in argon was used as the carrier gas and filtered through molecular sieve at a flow rate of 37 cm^3/min. The ECD was maintained at 218°C, standing current setting of 0.5, and oven was held isothermally at 125°C. The septums used were a low bleed type W from Applied Science Labs. Septums were changed every day to ensure a leak tight system. The glass column was sealed with 6.35 mm Graphloc ferrules from Applied Sciences. A 1 µℓ injection was used for all analyses. When the ECD was installed, a standing current vs pulse frequency curve was established and showed adequate sensitivity and a non-contaminated cell. The usual attenuation of 512 gave a 5 percent full scale deflection with a 0.2 ppb (490 ng/mℓ) standard.

A strip chart recorder provided a visual copy of the chromatogram for inspection and was operated at a speed of 1 cm/min. Peak area integration was acquired on a Spectra-Physics Minigrator and included retention time and peak area counts. All chromatograms were verified and sample concentrations were obtained from a standard curve that was verified daily with a minimum of three standards.

Standards were prepared by injecting 15 µℓ of pure perchloroethylene into a 50 mℓ volumetric flask and bringing to volume with 25 prcent CS_2 in methanol. The CS_2 was Baker-analyzed brand, and methanol was obtained from Burdick and Jackson. This dilution gave a 490-µg/mℓ perchloroethylene standard or 200 ppb equivalent ambient air sample. This stock solution was then diluted to 4.9 µ/mℓ, 2.44 µg/mℓ, and 0.244 µg/mℓ. The ppb concentrations were calculated assuming 24-hour sampling at 250 cm^3 or 360 liters. The linear concentration range for the ECD was between 0.49 µg/mℓ, or 0.49 ng total weight, using a 1 µℓ injection, to ~ 10 ng total weight. A standard curve was prepared by injecting 1 µℓ of each standard and a blank of CS_2/methanol, and plotting the area counts vs concentration.

A complete description of the measurement method employed appears in Appendix A.

SECTION 4

RESULTS AND DISCUSSION

The ambient air quality and meteorological data collected in the field monitoring program are presented in this section. In addition to the onsite meteorological measurements made by EPA, concurrent records of the U.S. National Weather Service (NWS) were obtained for each study area. These data, collected at municipal and regional airports, provide verification for the onsite measurements and a broader picture of the prevailing weather patterns and processes during the measurement of ambient PERC concentrations.

Since ambient PERC concentrations are determined as 24-hour integrated values (midnight-to-midnight), the meteorological data are summarized on a daily basis for intrepretative purposes. The individual entries in the tables describing meteorological conditions in the three metropolitan areas are defined below.

- Wind Direction - The most representative wind direction (a subjective evaluation in 45° increments) over a period of time during which the wind direction was fairly constant. This is based primarily on the NWS site closest to the center of the sampling area (e.g., LaGuardia in the New York area). Some adjustment, however, is made for the passage of a front or wave across the area. Major mesoscale differences, such as a sea breeze, are noted in the comments.

- Time - The period of the day over which the wind direction was constant. 01: is the hour average ending at 1 a.m., for continuous data, or the 00:53 observation at NWS sites.

- Wind Speed - The range of speeds in knots (KTS) which occurred for a given time period.

- Temperature - The minimum and maximum temperature for the day measured at the NWS site nearest the center of the sampling area.

- Mixing - A subjective evaluation (good, fair, or poor) of the dispersive ability of the atmosphere over the sampling area for the 24-hour period. Good implies clear skies during the day, good visibility, and moderate to strong wind speeds; poor implies a stagnation; and fair is everything else.

NEW YORK, NEW YORK

The NWS continuously monitors meteorological conditions at each of the three major airports serving the New York City metropolitan area (i.e., Newark, LaGuardia, and Kennedy). These locations form a triangle which encompasses the monitoring network established for the PERC field study. A compilation of the NWS data from these sites for the PERC sampling period appears as Table 5.

A comparison of the meteorological data collected by EPA with the NWS data summarized in Table 5 revealed that a serious discrepancy in observed wind direction existed throughout the study period. Since the difference was somewhat systematic and almost diametric, an explanation may be that the anemometer located at Site 6 was impacted by a local eddy effect, resulting in a bias in recorded wind direction. At any rate, the NWS data were considered the more reliable measure of the wind patterns affecting the metropolitan New York area during the course of the study. The NWS data from LaGuardia and the EPA data from Site 6 appear in Appendix B.

The ambient concentrations of PERC observed in the New York area are summarized by site and date in Table 6. Measurable quantities (i.e., $\geq$0.10 ppb) were detected at each site and on each day for which data are available. Individual concentrations range from 0.16 to 10.61 and average 1.33 ppb.

The daily average concentrations (right hand column) reveal a marked day-of-week pattern in which the highest levels of PERC occur during mid-week (i.e., Tuesday through Thursday) with lower concentrations prevailing Friday through Monday. Minimum concentrations were observed on the two Sundays included in the sampling period. These findings are consistent with the expected activity pattern of perchloroethylene emission sources.

The average concentrations by sampling site are shown across the bottom of the table. Minimum ambient PERC levels were found at Sites 1 and 10 which are both characterized as background locations (Table 2). The highest concentrations were consistently observed at Site 6 and, to a lesser extent, Site 7. As discussed in Section 3, these sites are located in heavily industrialized sections of Queens, and at least one point source of PERC (an industrial dry cleaning plant) lies within the immediate vicinity of the Greenpoint Treatment Plant (Site 6). The other six sites, all in residential and/or commercial neighborhoods, exhibited less variation in concentration for the 10-day study period. The ambient PERC data are displayed on an area plot for each day of the study in Figures 5 through 14.

A meaningful evaluation of the meteorological processes of diffusion and transport on a day-to-day basis is complicated by the ubiquitous nature of PERC emissions and the constraint of time-averaged concentration measurements. Generally, however, it appears that instances of relatively high ambient PERC concentrations throughout the study area are accompanied by light and variable winds and less than good mixing conditions (e.g., 8/26/78).

Table 5. NATIONAL WEATHER SERVICE DATA FROM NEW YORK, NEW YORK, 8/18/78 – 8/27/78

8/18/78 – 8/27/78

Date Aug:	Wind Direction	Time	Wind Speed (KTS)	Temp. Min/Max (°F, °C)	Mixing	Comments
18	NW	01–21	5–10	71/82	G	
	NE	22–00	5–10	22/28		
19	NE	01–09	4–8	68/88	G	Sea Breeze effect seen closer to ocean
	S to W	10–18	5–10	20/31		
	SW	19–00	5–10			
20	SW	01–08	3–6	71/81	G	
	NW to N	09–00	8–15	22/27		
21	N to NE	01–12	8–12	65/80	G	Sea Breeze close to shore
	NE	13–18	8–14	18/27		
	SE to S	19–00	3–7			
22	N	01–06	4–7	65/83	G	Sea Breeze near coast, more Southerly winds
	NE	07–15	5–7	18/28		
	S to SW	16–00	6–10			
23	SW	01–04	5–7	67/85	F	Some Sea Breeze
	NW	05–17	5–8	19/29		
	W	18–00	5–7			
24	W	01–05	4–7	71/86	F	Cloudy with haze
	SW	06–20	6–11	22/30		
	NE	21–00	11–14			
25	NE	01–00	5–15	61/71 16/22	F	Overcast, occasional fog and drizzle
26	N	01–09	4–8	61/76	F	Winds light and variable all day
	NE	10–17	5–8	16/24		
	S to SW	18–00	5–10			
27	SW	01–06	4–7	66/80	F	Haze most of day
	NE	07–14	8–10	19/27		
	SE to S	15–00	8–14			

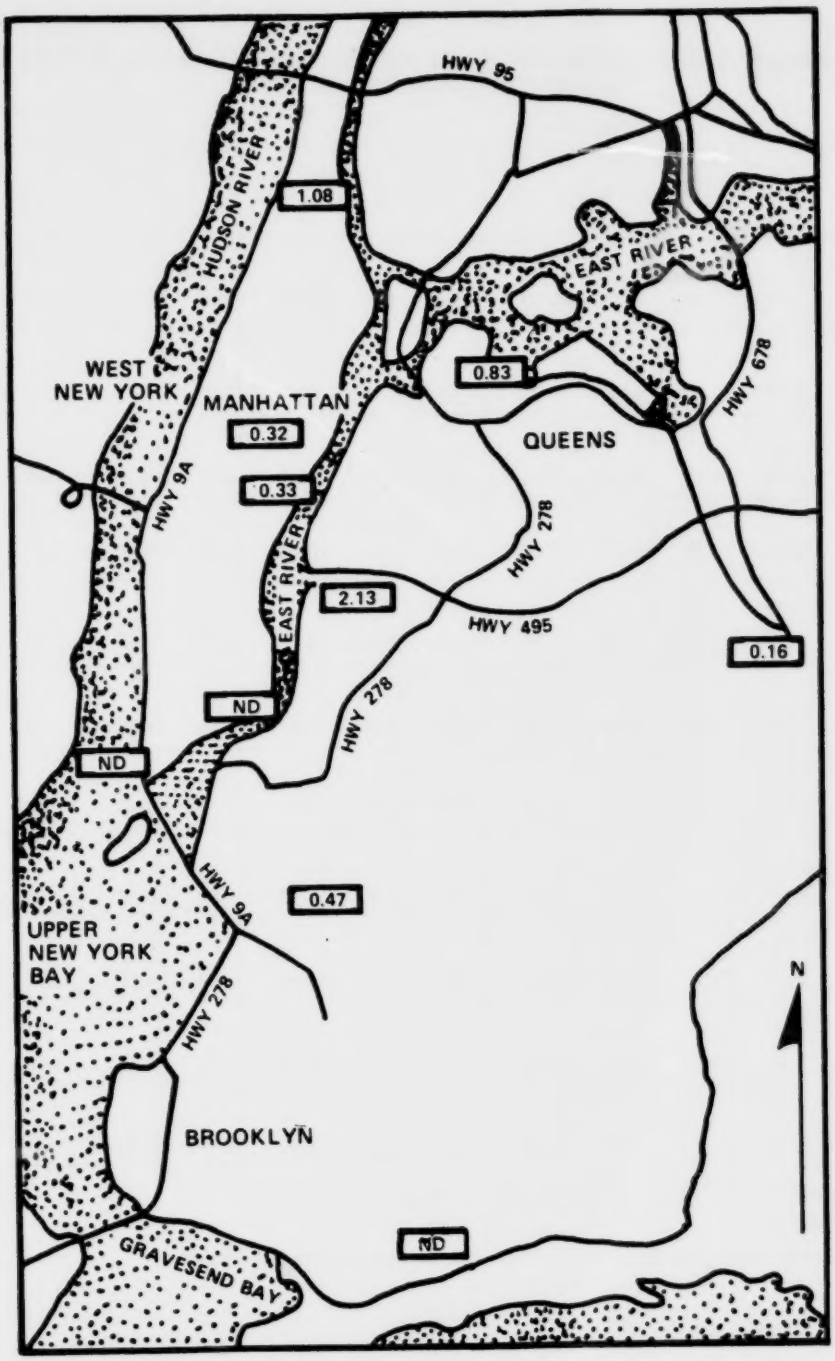
Table 6. AMBIENT CONCENTRATIONS OF PERCHLOROETHYLENE IN NEW YORK, NEW YORK, 8/18/78 – 8/27/78

Site / Date	1	2	3	4	5	6	7	8	9	10	Daily Average
Friday 8/18/78	ND	ND	0.33	0.32	1.08	2.13	0.83	0.47	0.16	ND	0.76
Saturday 8/19/78	0.72	0.69	0.64	0.86	0.83	2.32	0.82	1.22	0.55	0.30	0.90
Sunday 8/20/78	0.29	0.17	0.26	0.26	0.38	0.75	0.49	0.37	0.28	ND	0.36
Monday 8/21/78	0.40	1.30	1.27	0.41	0.83	2.53	0.49	0.90	0.29	0.43	0.89
Tuesday 8/22/78	1.03	1.04	1.76	1.74	1.70	10.61	1.75	1.71	0.81	1.00	2.32
Wednesday 8/23/78	1.28	1.86	1.44	1.29	2.09	6.44	2.89	1.77	1.64	1.16	2.19
Thursday 8/24/78	1.10	1.33	2.11	1.64	1.37	4.27	4.42	1.72	2.36	1.06	2.14
Friday 8/25/78	0.60	2.03	1.48	0.88	1.71	3.00	0.92	1.98	0.72	0.35	1.37
Saturday 8/26/78	0.50	1.21	1.01	0.80	1.06	4.10	1.60	2.48	1.05	0.91	1.47
Sunday 8/27/78	0.46	0.67	0.87	0.46	0.46	ND	0.66	0.58	0.47	0.56	0.58
Site Average	0.71	1.14	1.12	0.87	1.15	4.02	1.49	1.32	0.83	0.72	1.33

NOTE: All results are twenty-four-hour integrated values expressed in ppb.

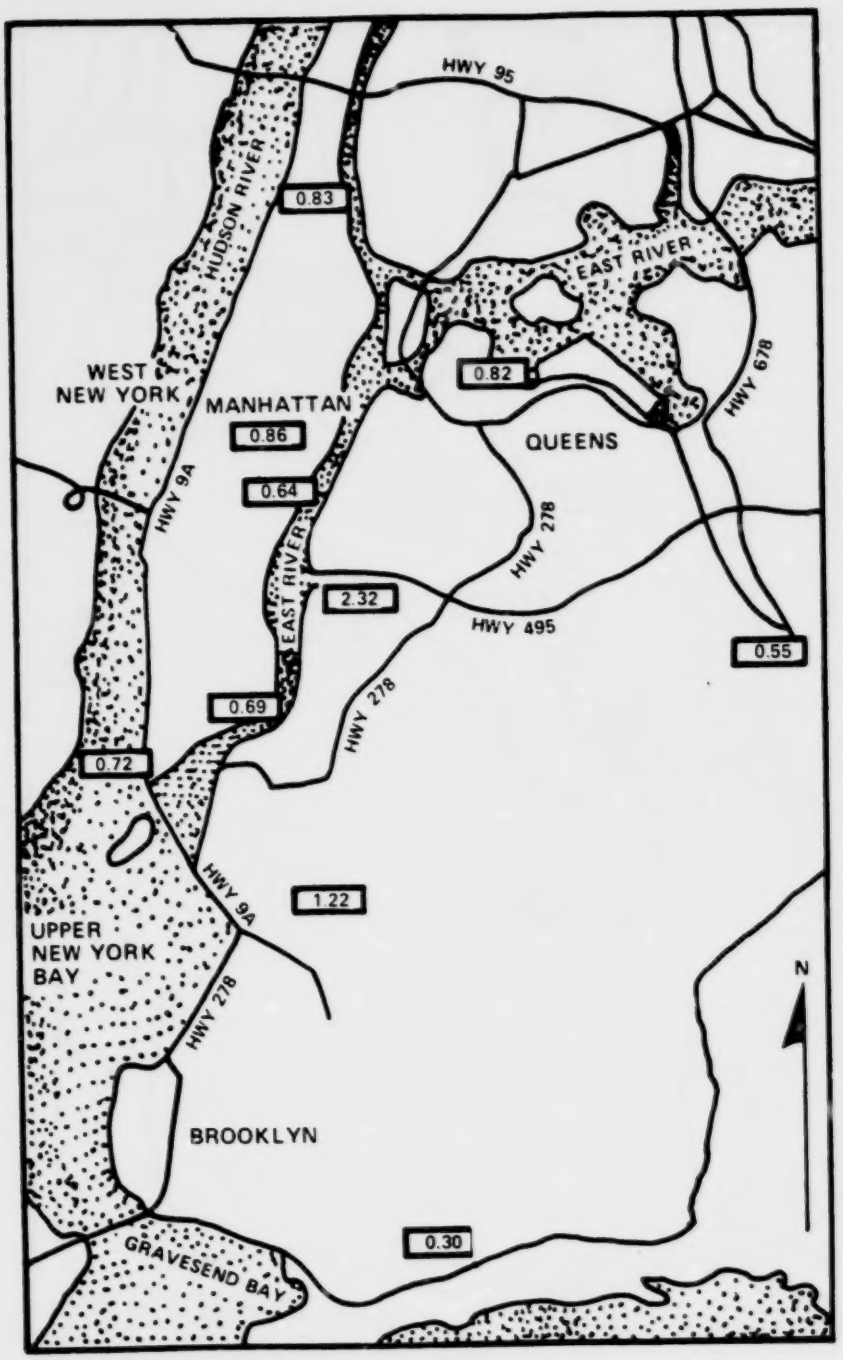
ND= No Data

BD= Below Detectable (estimated at 0.05 ppb for computation of averages)



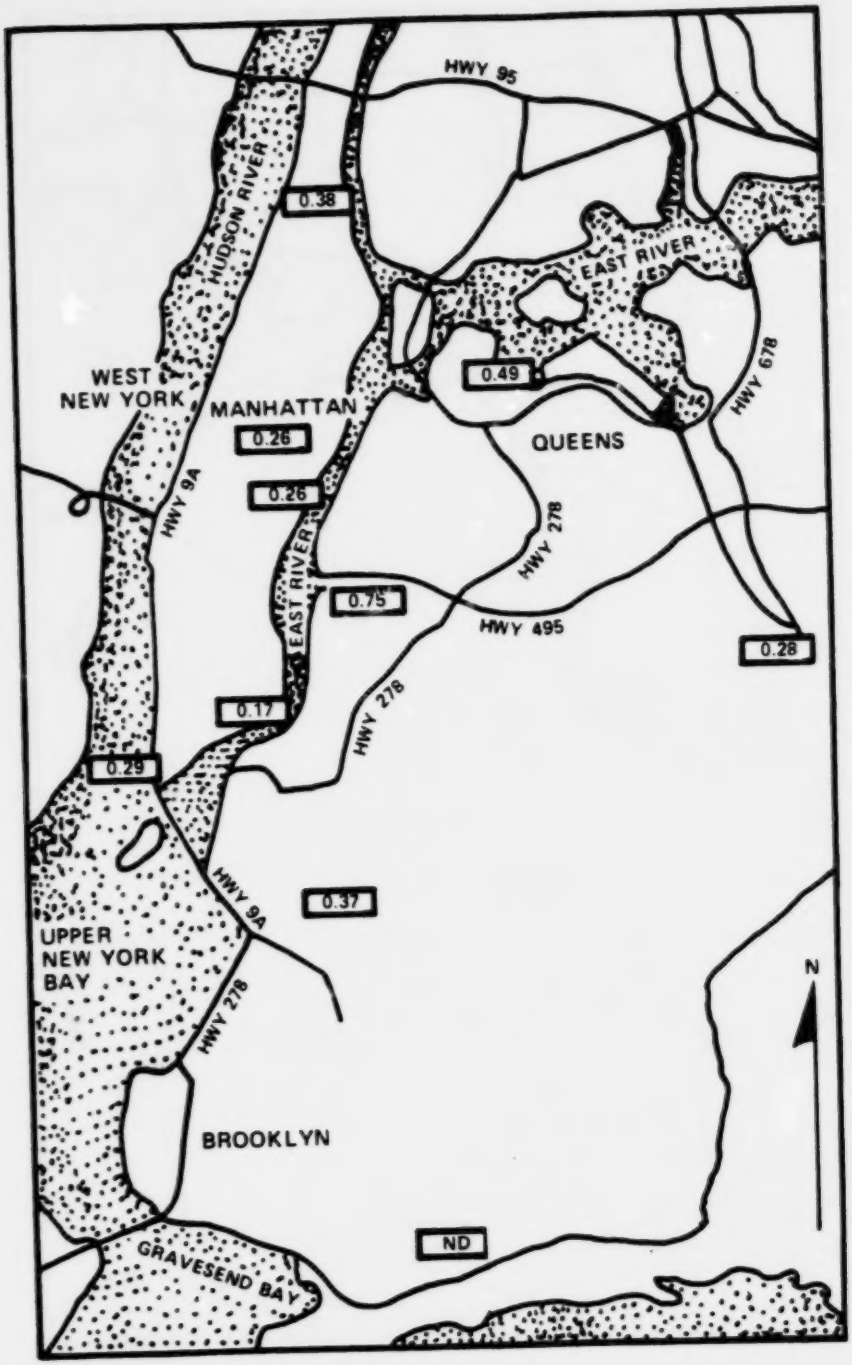
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 5. Ambient concentrations of perchloroethylene in New York, New York, Friday, 8/18/78.



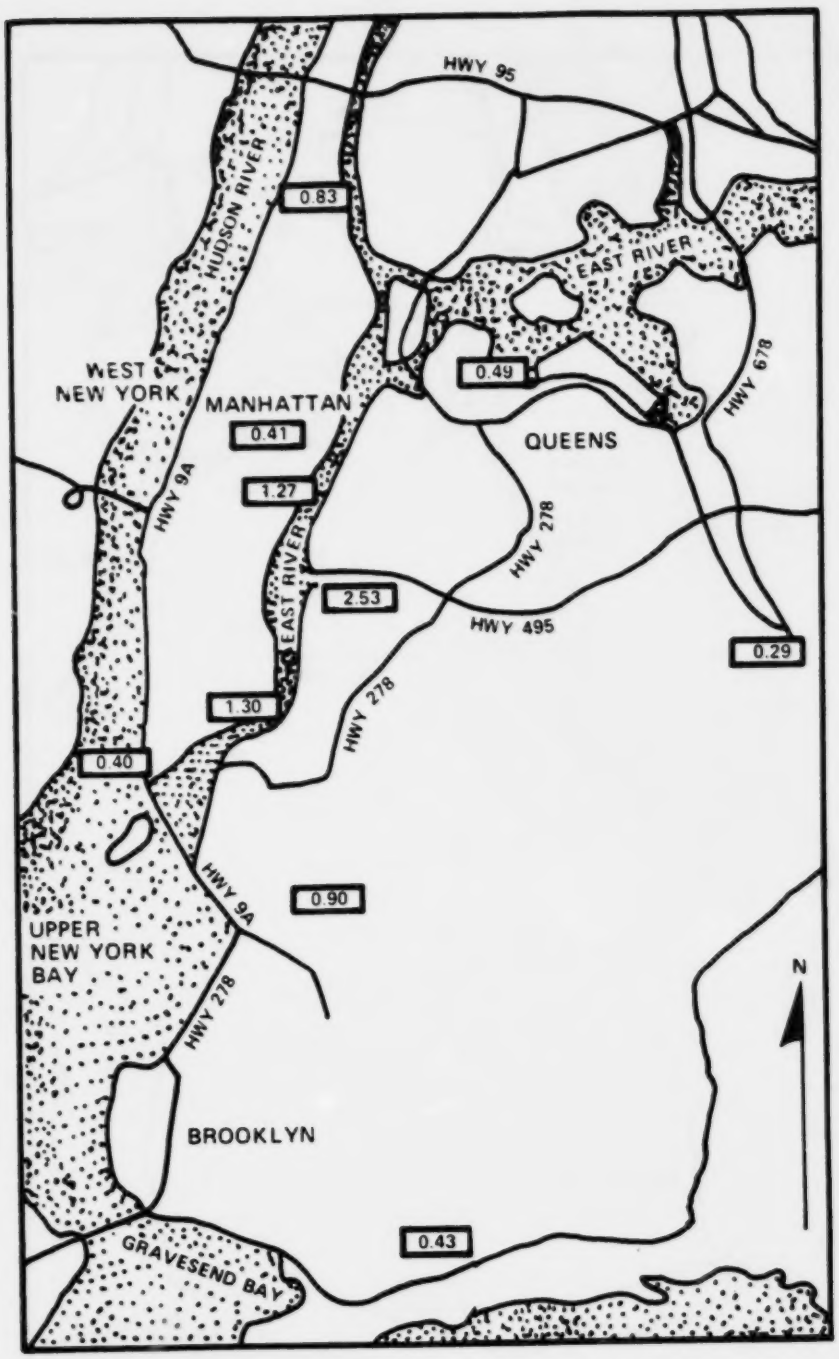
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 6. Ambient concentrations of perchloroethylene in New York, New York, Saturday, 8/19/78.



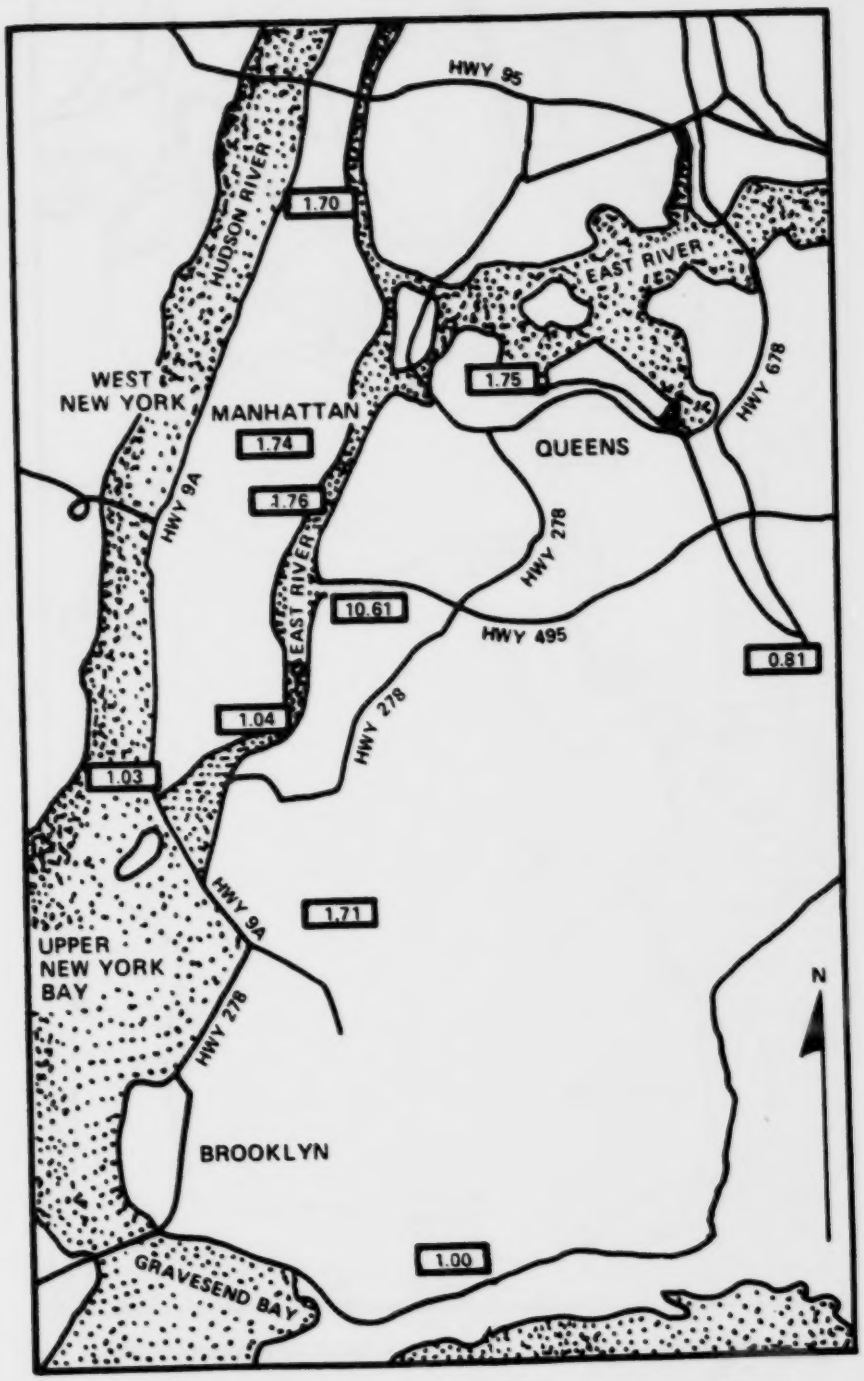
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 7. Ambient concentrations of perchloroethylene in New York, New York, Sunday, 8/20/78.



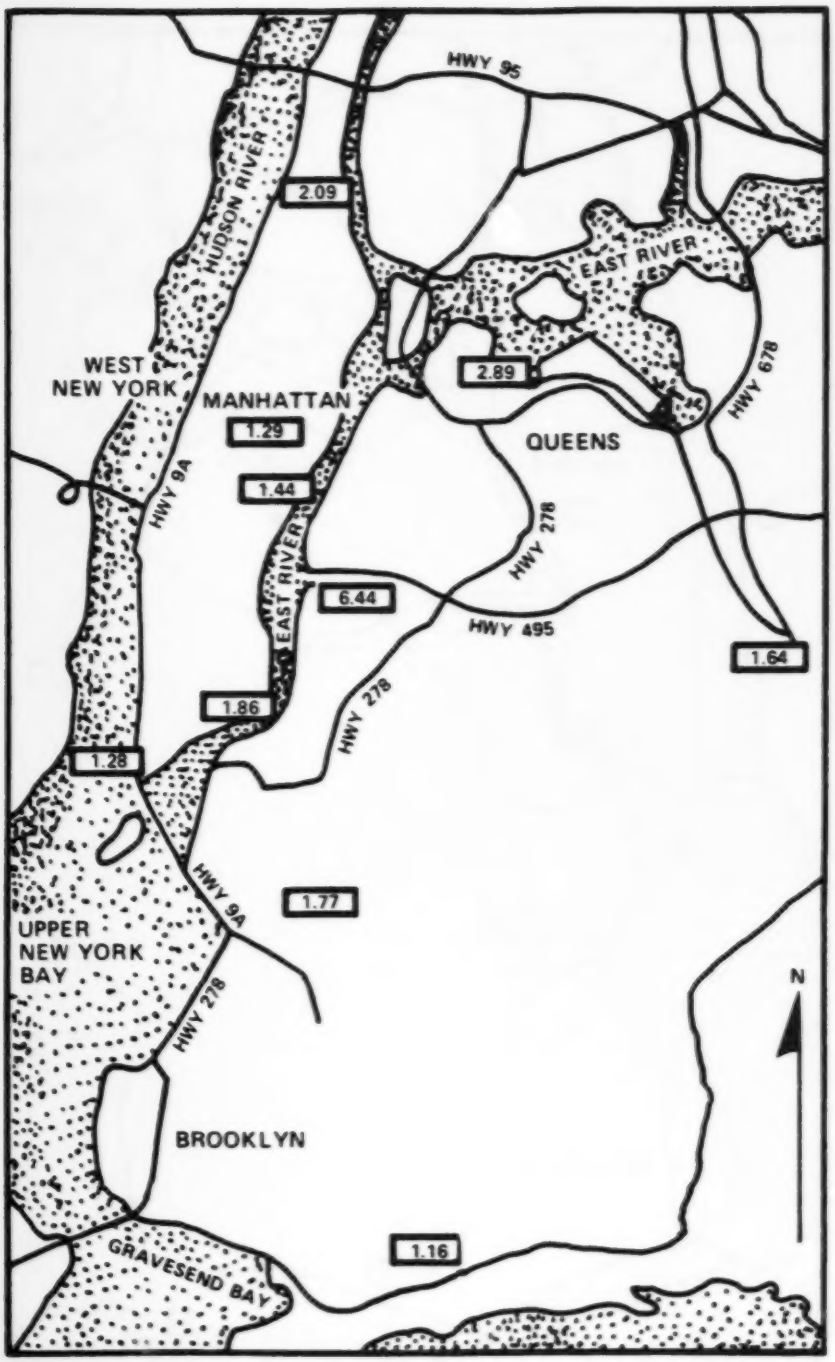
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 8. Ambient concentrations of perchloroethylene in New York, New York, Monday, 8/21/78.



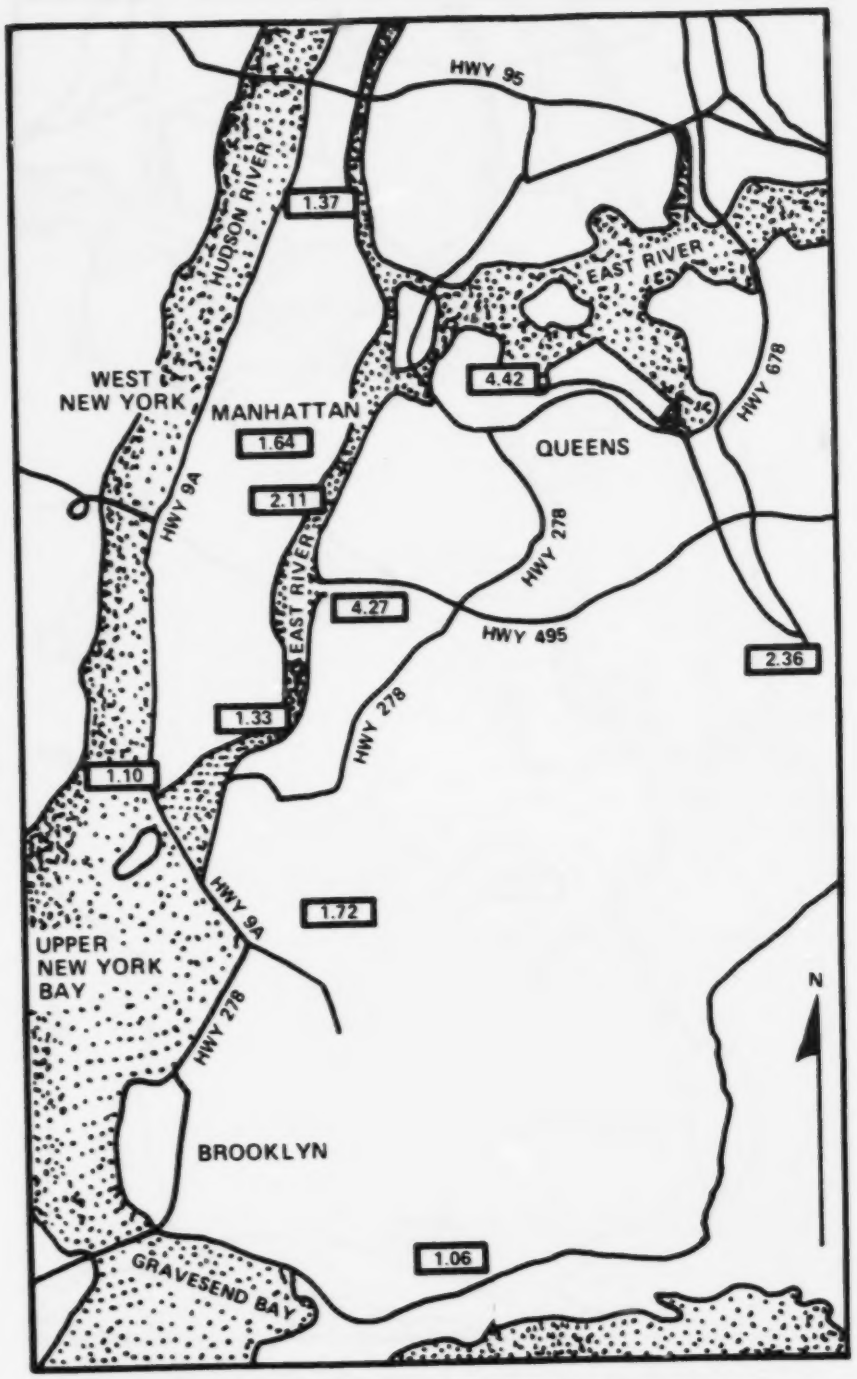
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 9. Ambient concentrations of perchloroethylene in New York, New York, Tuesday, 8/22/78.



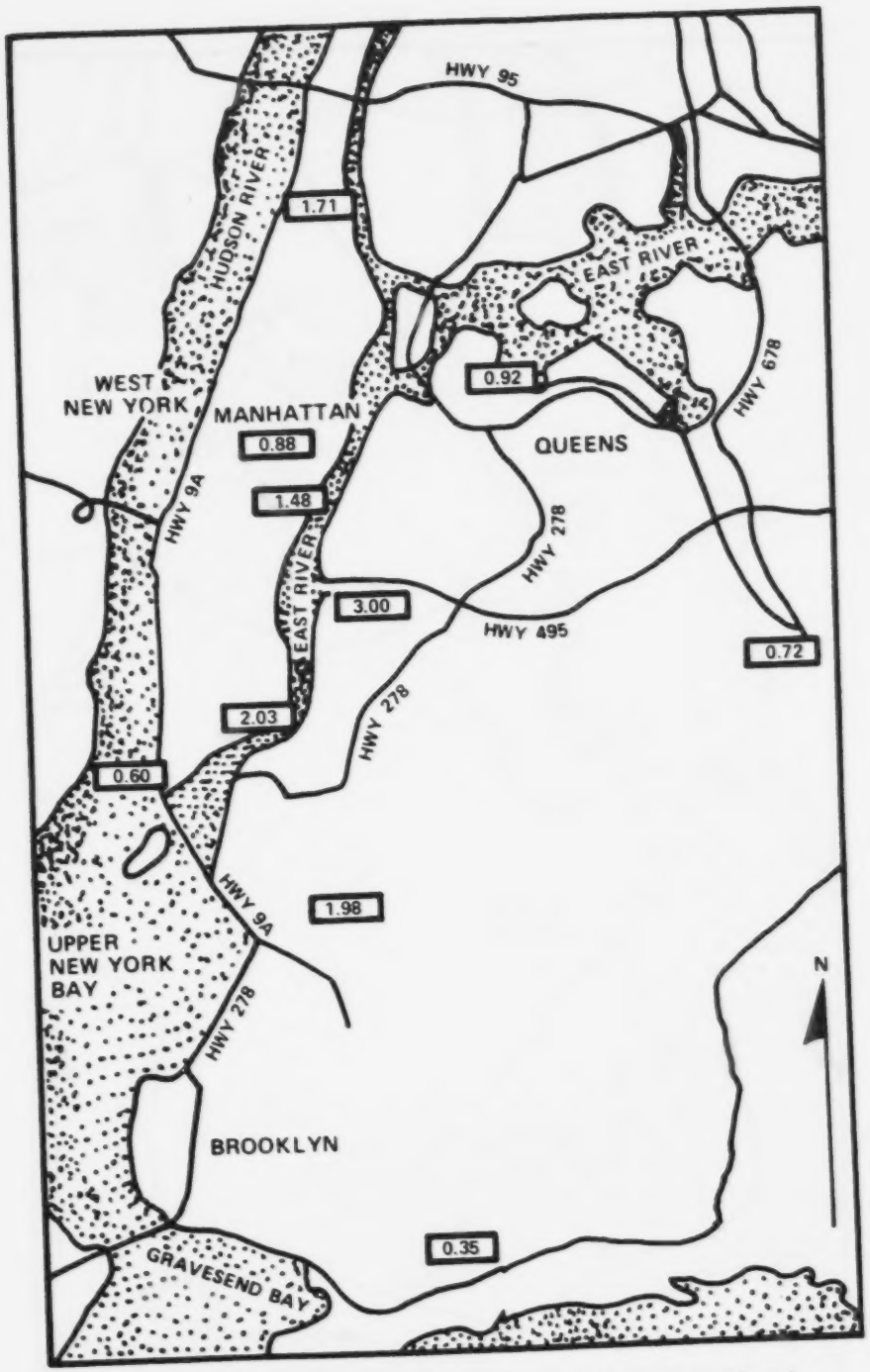
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 10. Ambient concentrations of perchloroethylene in New York, New York, Wednesday, 8/23/78.



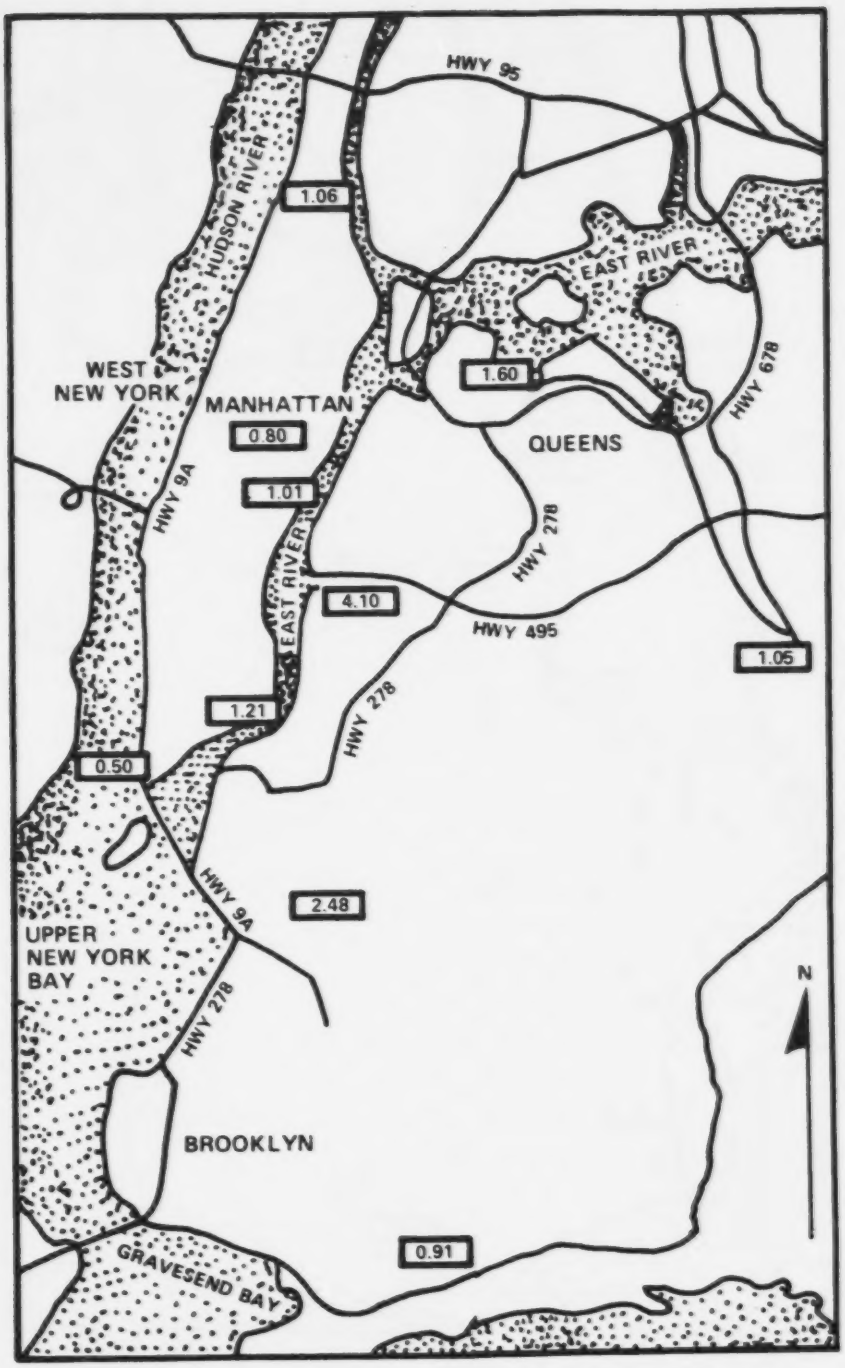
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 11. Ambient concentrations of perchloroethylene in New York, New York, Thursday, 8/24/78.



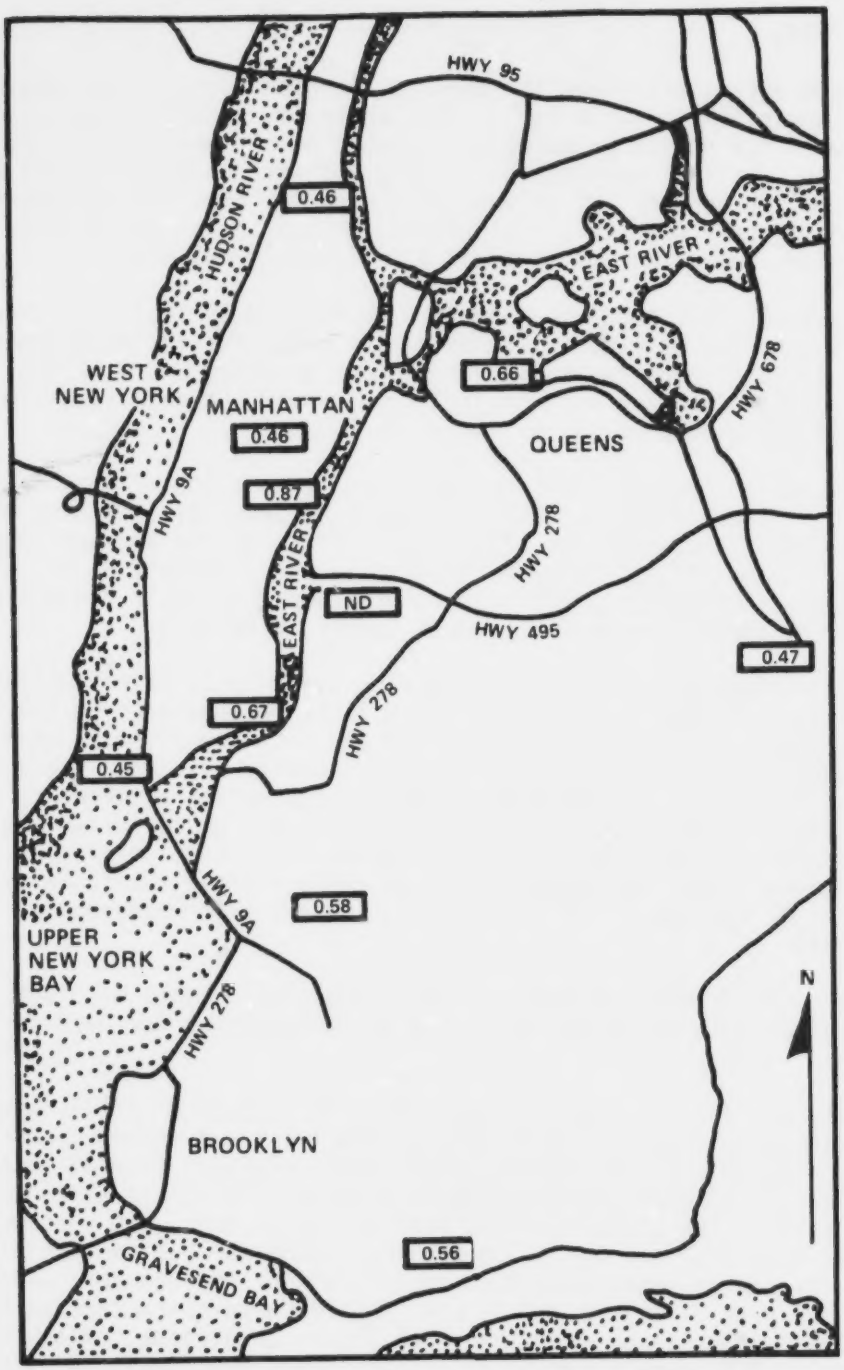
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 12. Ambient concentrations of perchloroethylene in New York, New York, Friday, 8/25/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 13. Ambient concentrations of perchloroethylene in New York, New York, Saturday, 8/26/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

Figure 14. Ambient concentrations of perchloroethylene in New York, New York, Sunday, 8/27/78.

HOUSTON, TEXAS

Meteorological data from the NWS reporting stations in the Houston area are summarized in Table 7. In this instance, excellent agreement was found between the onsite meteorological measurements and those obtained from NWS, and very distinct meteorological patterns were observed during the Houston sampling period. Winds were predominantly from the southeast through the first 4 days and, following a 2-day transitional period, northeasterly winds dominated the final 4 days of sample collection.

The ambient PERC concentrations are summarized in Table 8. Forty-three samples (46 prcent) were below the detection limit for the measurement method (0.10 ppb). The maximum concentration observed was 4.52 ppb. An overall average, computed by substituting one-half the detection limit for the indeterminate samples, is estimated at 0.39 ppb.

The average concentrations by day demonstrate a day-of-week pattern similar to that observed in New York. Again, higher levels tended to occur during midweek (Tuesday through Thursday). Although the average concentration computed for Friday, 9/22/78, appears to be relatively high, this value is inordinately affected by a single observation (Site 9). The minimum daily average concentration occurred on Sunday, 9/24/78.

The distribution of PERC concentrations by site is fairly uniform with the exception of Sites 3, 7, and 9. It will be remembered from the discussion of siting criteria that Site 3 is in the vicinity of an industrial dry cleaning plant while Sites 7 and 9 were selected to bracket a major PERC production facility. The minimum average concentration occurred at the suburban location (Site 10), but this value was not appreciably lower than those associated with urban locations removed from known point sources of PERC emissions. Absolute quantitative comparison among sites, however, is handicapped by the number of indeterminate (i.e., below detectable) observations.

Figures 15 through 24 combine PERC concentration data with the meteorological data collected at Site 8 on an area plot for each day of the study.

During the first 4 sampling days (9/16/78 through 9/18/78), winds were consistently from the south through southwest and mixing conditions were generally good. Under these conditions, emissions from Diamond Shamrock appear to have had more impact at Site 7, which is north and slightly west of the plant, than at Site 9 (equidistant, but southwest of the plant). With the exception of Site 3, the other sites exhibited less than or barely detectable PERC concentrations through this 4-day period. The next 2 days (9/20/78 and 9/21/78) were characterized by light and variable winds, rain, and diminished mixing conditions. Measurable quantities of PERC were observed at all sampling locations on each of these 2 days. Finally, a strong northeasterly wind system was established which persisted through the last 4 days of sample collection (9/22/78 through 9/25/78). During this period, relatively high PERC concentrations were observed at Site 9 and Site 3, while PERC concentrations at the sites in

Table 7. NATIONAL WEATHER SERVICE DATA FROM HOUSTON, TEXAS, 9/16/78 – 9/25/78

Date Sept:	Wind Direction	Time	Windspeed (KTS)	Temp. Min/Max (°F, °C)	Mixing	Comments
16	SE SW SE	01–08 09–13 14–00	0–3 3–8 5–10	72/90 22/32	F	Very light rain on the N. side of town
17	SE	ALL	5–15	74/89 23/32	G	
18	SE	ALL	5–10	74/92 23/33	G	
19	SE	ALL	5–10	75/92 24/33	G	
20	calm NE SE–SW	01–05 06–08 09–00	5–8 0–12	74/88 23/31	F	Scattered rain showers, some quite heavy; 2.6" accumulation in town
21	NE SE NE	01–06 07–19 20–00	0–5 5–12 5–7	73/89 23/32	F	Light rain on North side of town
22	N NE–E NE	01–09 10–18 19–00	5–12 10–15 8–12	74/88 23/31	F	Fog & Haze with a trace of rain, morning and evening
23	NE	ALL	5–10	71/82 22/28	F	Fog & Haze all day
24	NE	ALL	6–12	69/85 21/30	G	
25	NE	ALL	6–12	64/84 18/29	G	

Table 8. AMBIENT CONCENTRATIONS OF PERCHLOROETHYLENE IN HOUSTON, TEXAS, 9/16/78 – 9/25/78

Date \ Site	1	2	3	4	5	6	7	8	9	10	Daily Average
Saturday 9/16/78	BD	0.10	0.71	ND	ND	ND	0.37	BD	BD	0.28	0.23
Sunday 9/17/78	BD	BD	0.11	BD	BD	ND	1.38	BD	BD	0.11	0.21
Monday 9/18/78	0.10	BD	1.25	0.14	0.10	BD	2.37	BD	BD	BD	0.42
Tuesday 9/19/78	0.26	BD	0.42	0.14	0.20	0.39	3.32	BD	BD	0.27	0.52
Wednesday 9/20/78	0.38	0.24	0.60	0.57	0.67	0.73	1.51	0.49	0.12	0.19	0.55
Thursday 9/21/78	0.77	0.64	4.52	0.43	0.42	0.29	0.21	0.38	0.27	0.22	0.82
Friday 9/22/78	0.13	BD	2.46	0.10	BD	BD	BD	BD	3.19	BD	0.62
Saturday 9/23/78	0.12	0.22	0.52	BD	BD	BD	BD	BD	BD	BD	0.12
Sunday 9/24/78	BD	BD	0.36	BD	BD	BD	BD	BD	0.26	BD	0.10
Monday 9/25/78	0.16	0.20	2.05	BD	BD	BD	BD	BD	0.55	BD	0.33
Site Average	0.21	0.17	1.30	0.18	0.18	0.21	0.94	0.13	0.46	0.13	0.39

NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND= No Data
BD= Below detectable (estimated at 0.05 ppb for computation of averages)

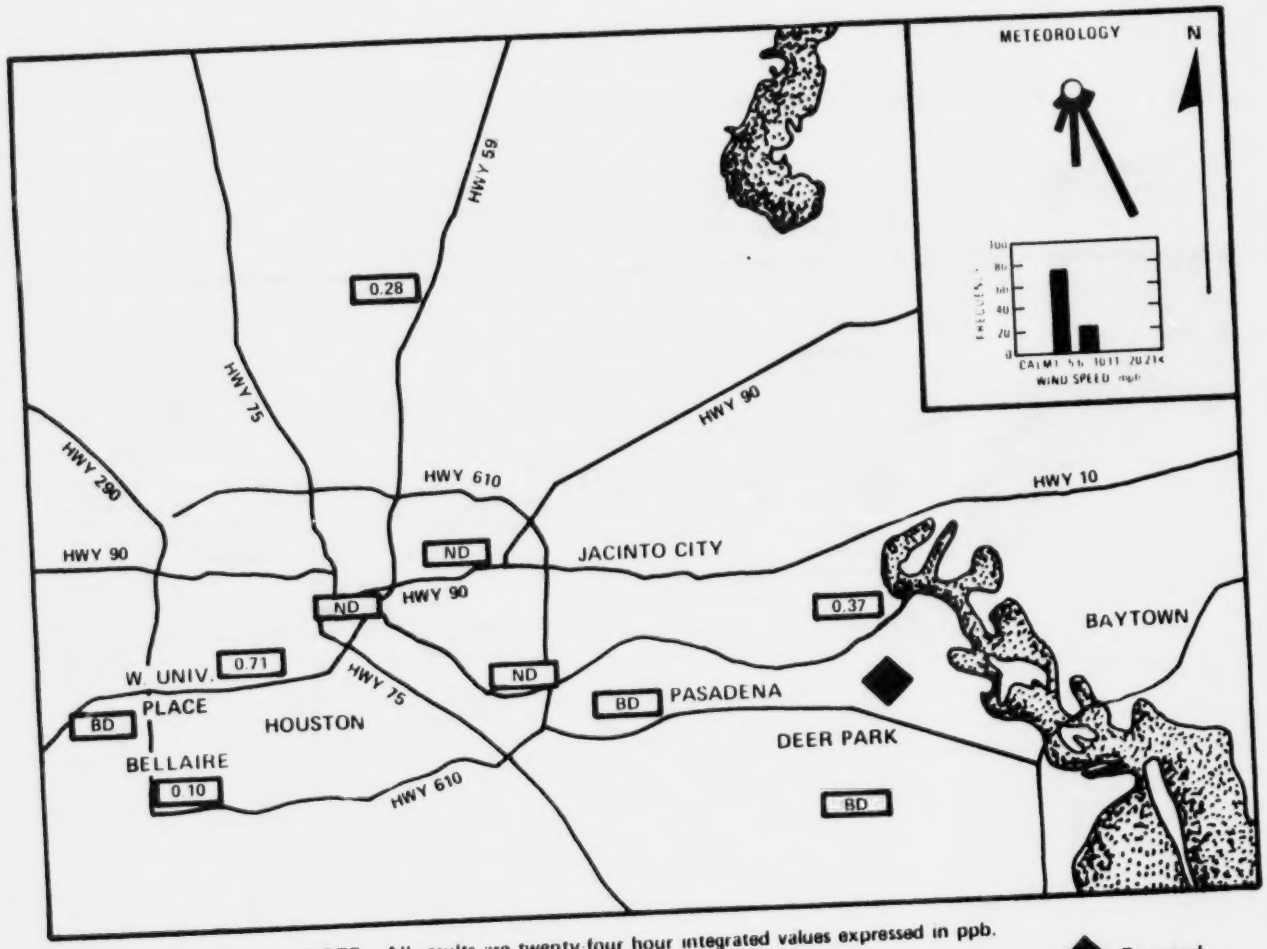


Figure 15. Ambient concentrations of perchloroethylene in Houston, Texas, Saturday, 9/16/78.

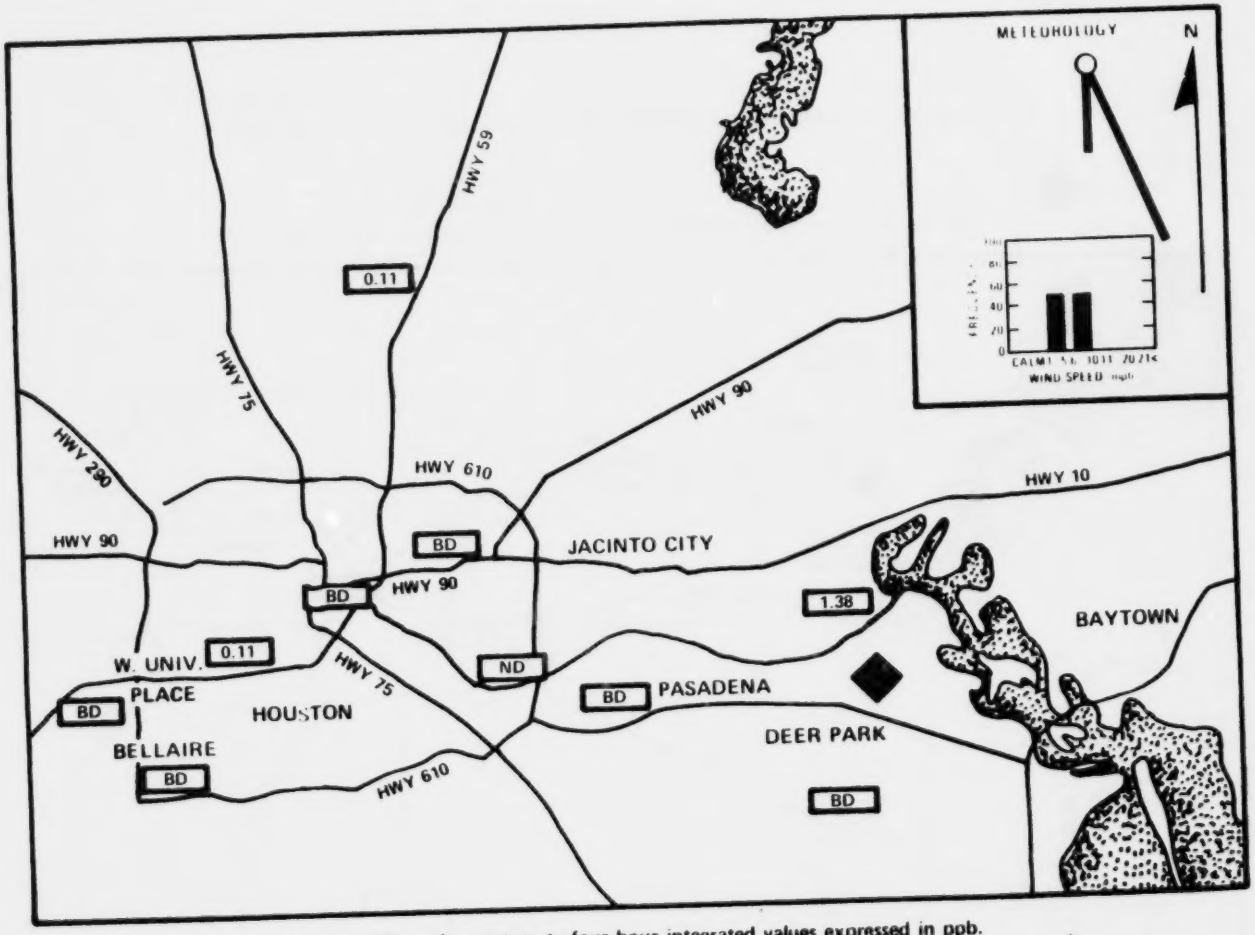


Figure 16. Ambient concentrations of perchloroethylene in Houston, Texas, Sunday, 9/17/78.

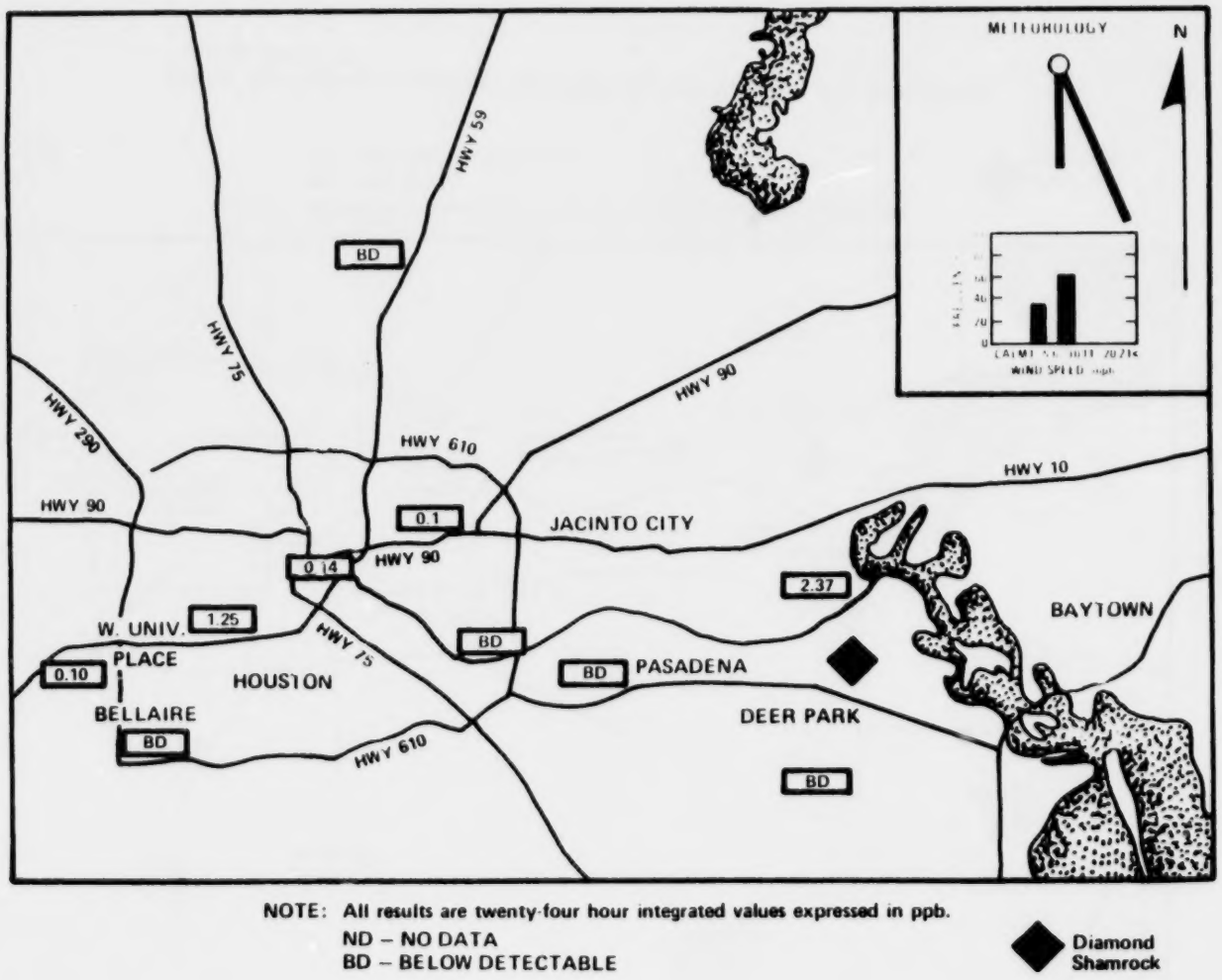


Figure 17. Ambient concentrations of perchloroethylene in Houston, Texas, Monday, 9/18/78.

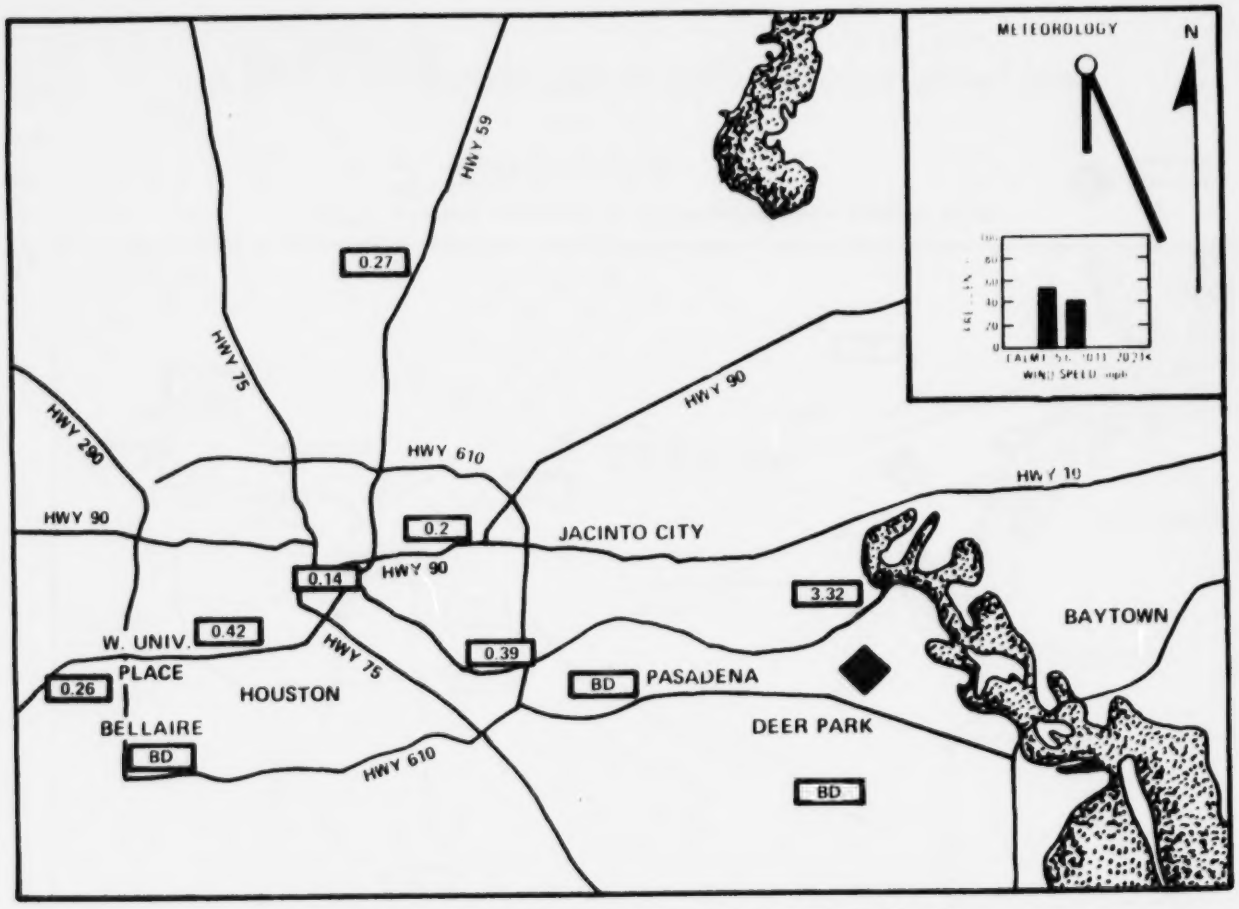


Figure 18. Ambient concentrations of perchloroethylene in Houston, Texas, Tuesday, 9/19/78.

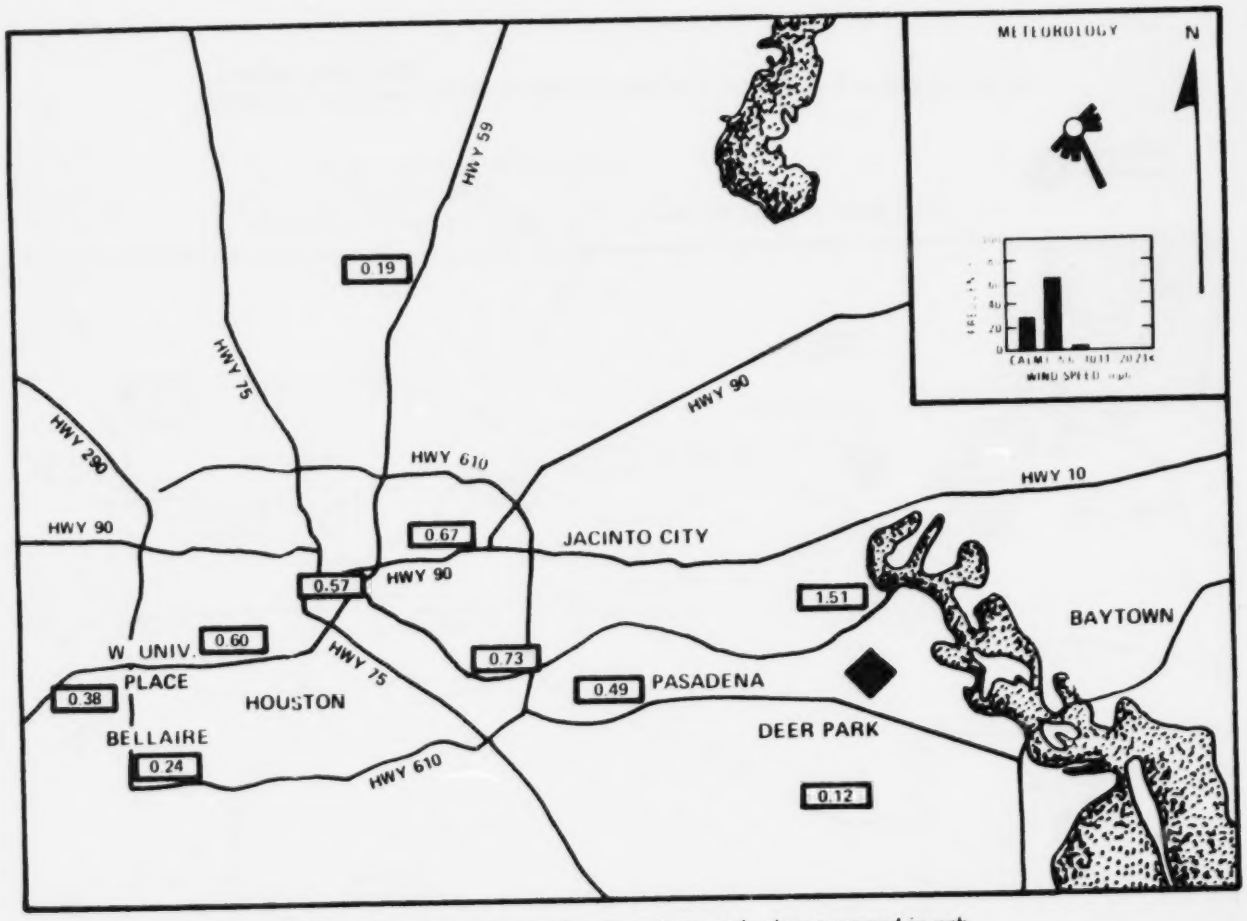


Figure 19. Ambient concentrations of perchloroethylene in Houston, Texas, Wednesday, 9/20/78.

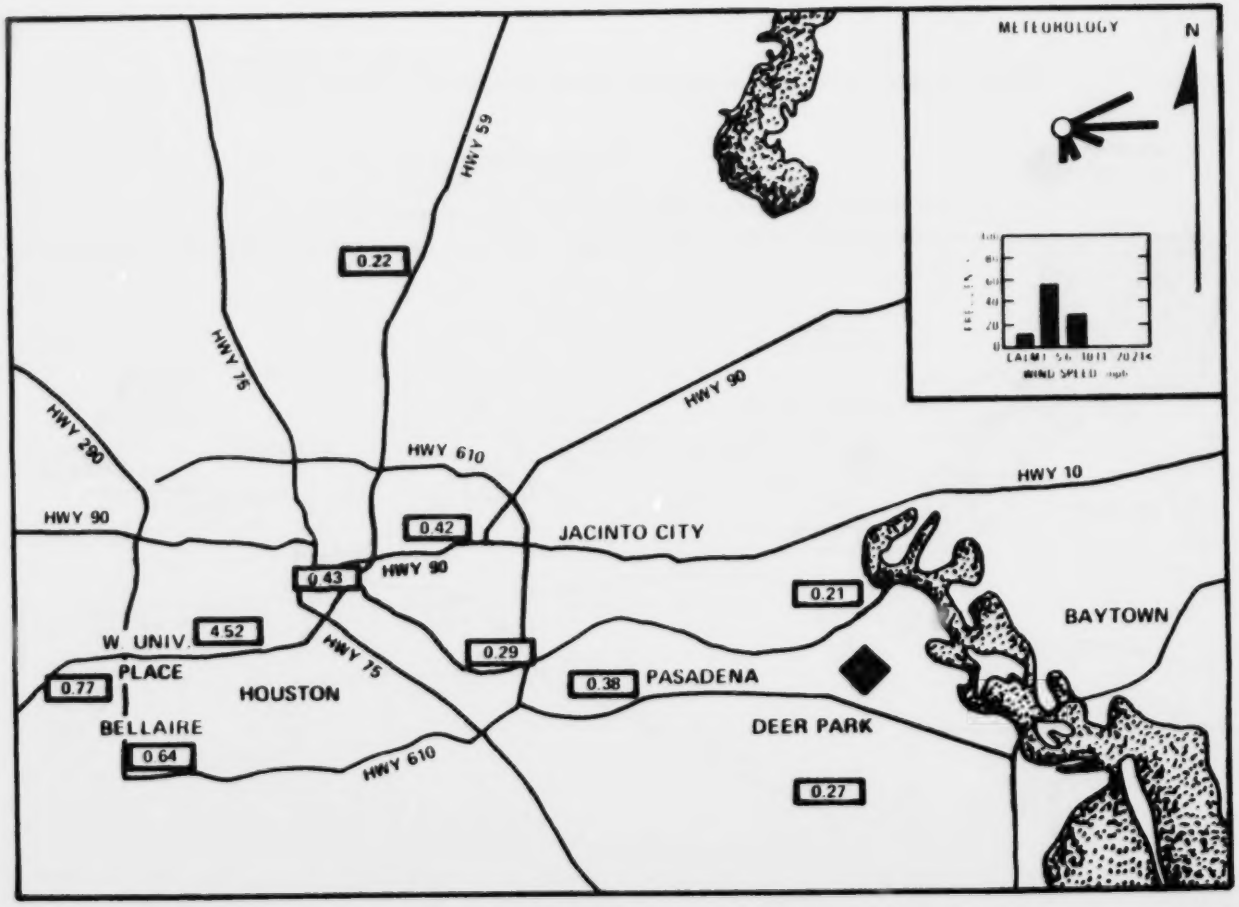
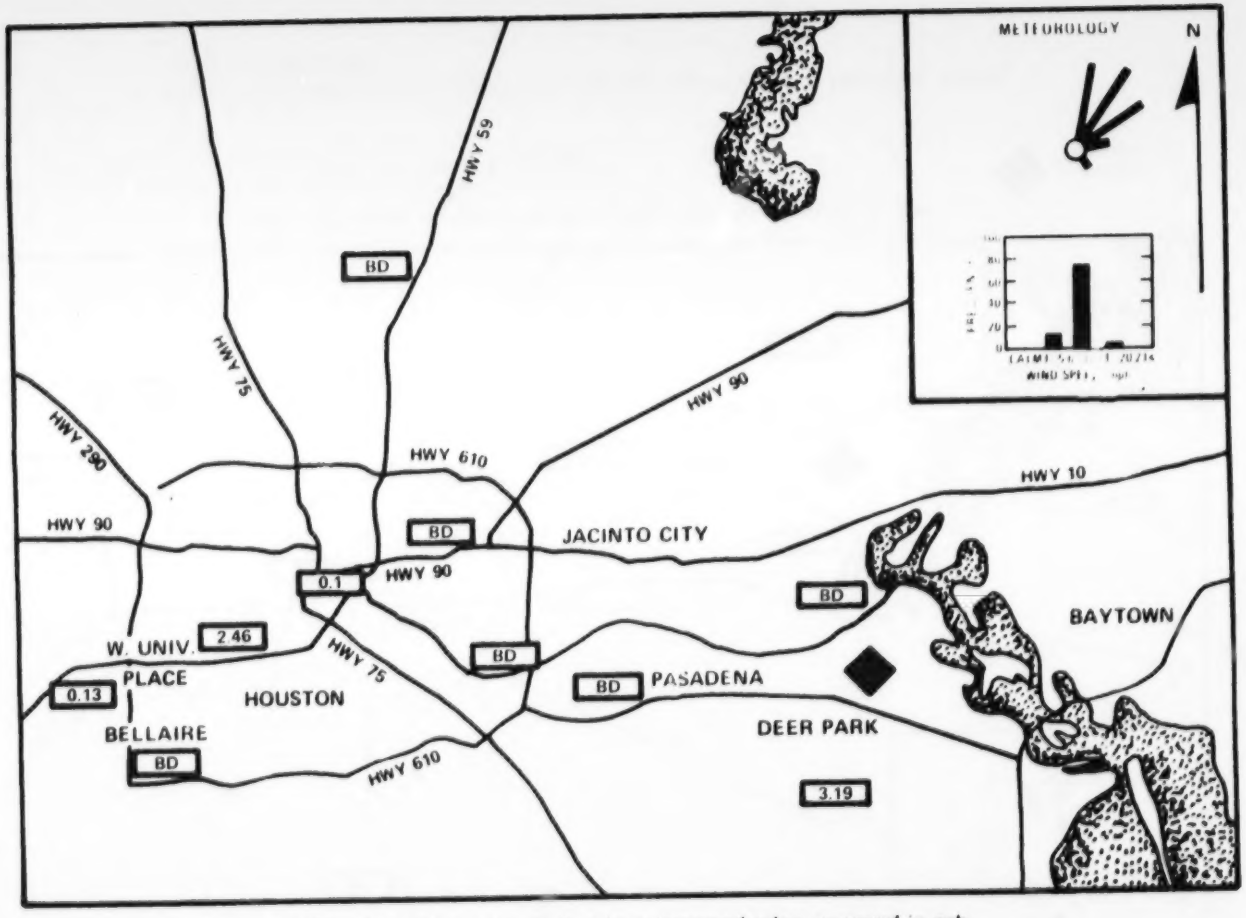


Figure 20. Ambient concentrations of perchloroethylene in Houston, Texas, Thursday, 9/21/78.



NOTE: All results are twenty-four hour integrated values expressed in ppb.
ND – NO DATA
BD – BELOW DETECTABLE

◆ Diamond Shamrock

Figure 21. Ambient concentrations of perchloroethylene in Houston, Texas, Friday, 9/22/78.

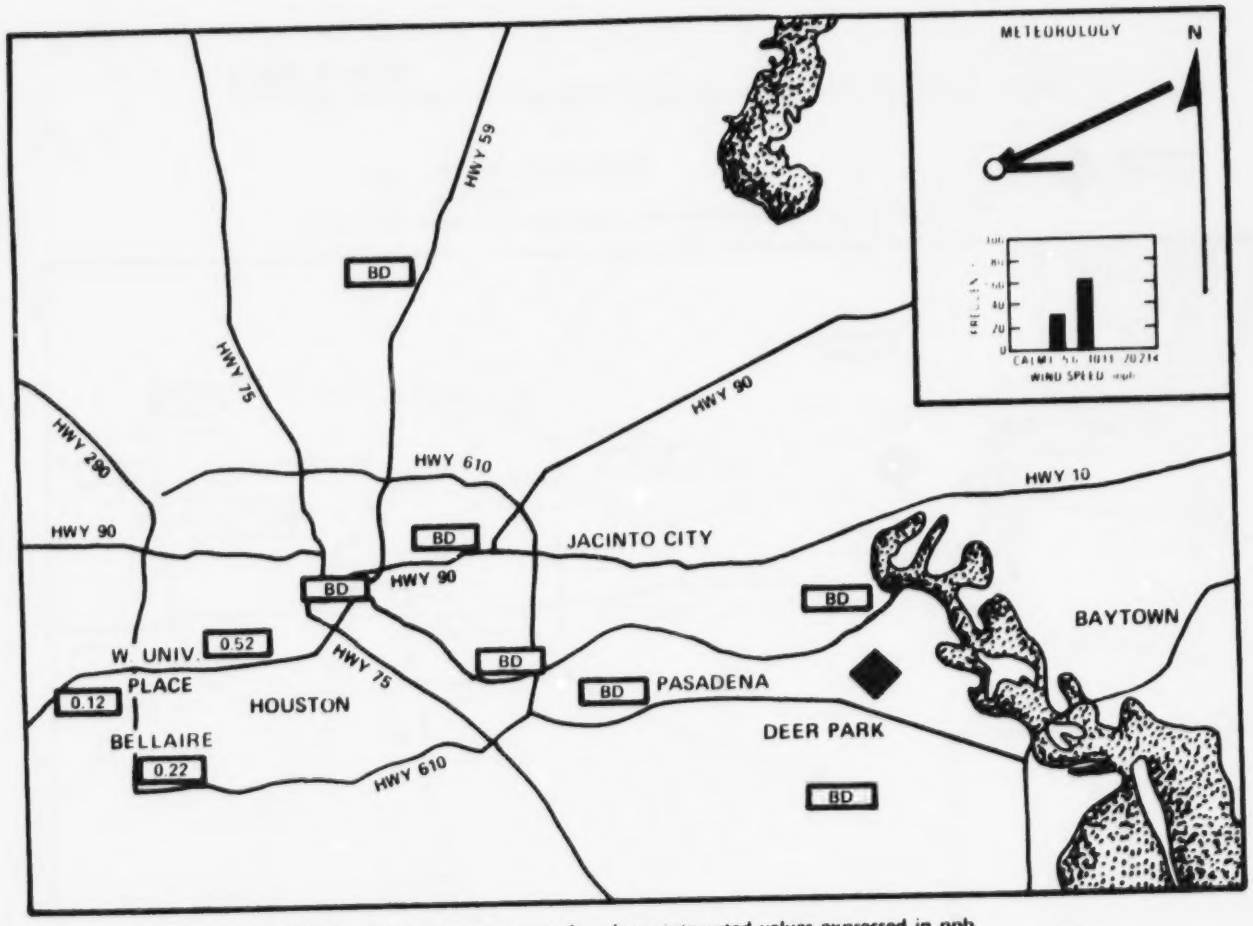


Figure 22. Ambient concentrations of perchloroethylene in Houston, Texas, Saturday, 9/23/78.

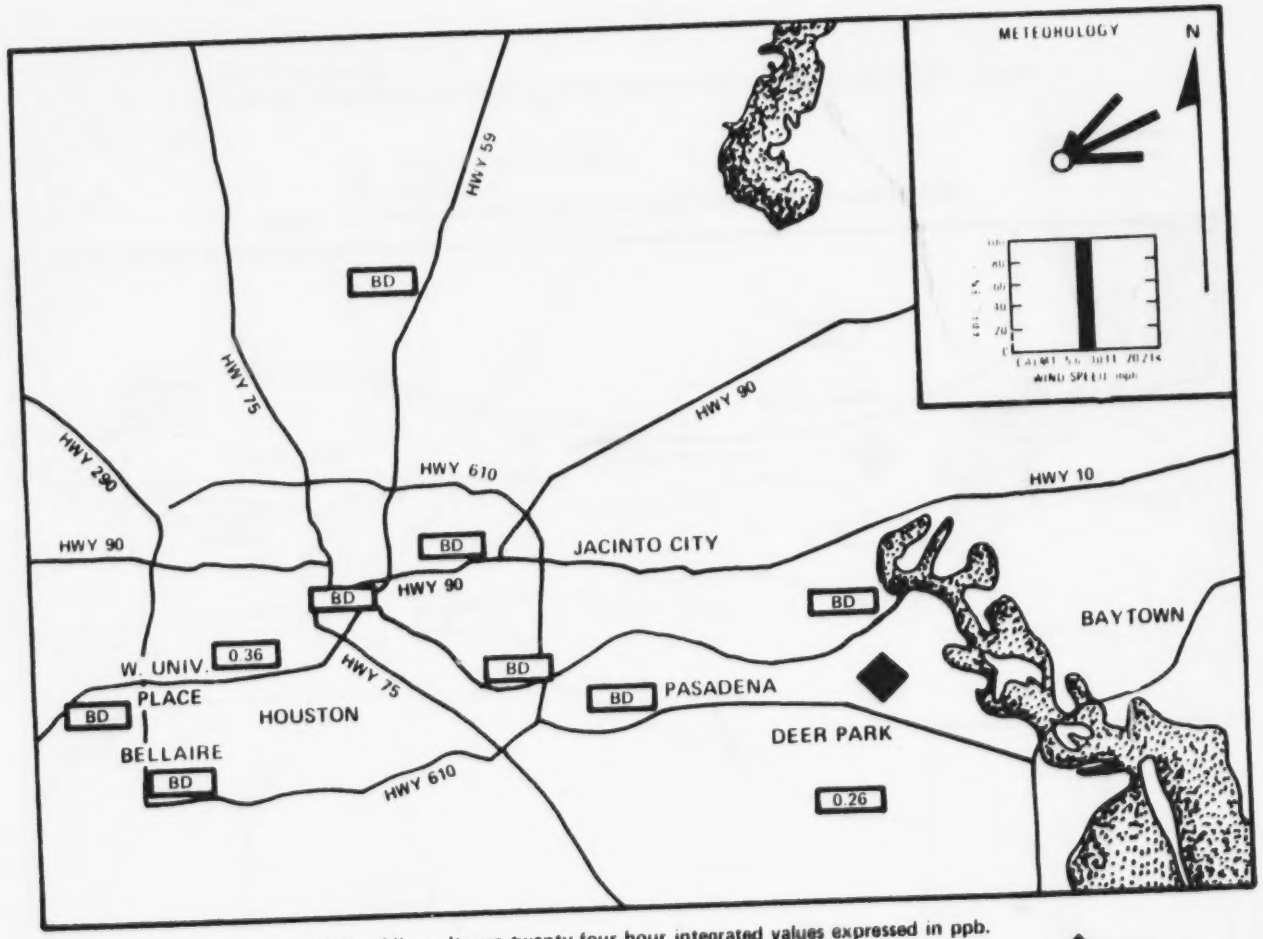


Figure 23. Ambient concentrations of perchloroethylene in Houston, Texas, Sunday, 9/24/78.

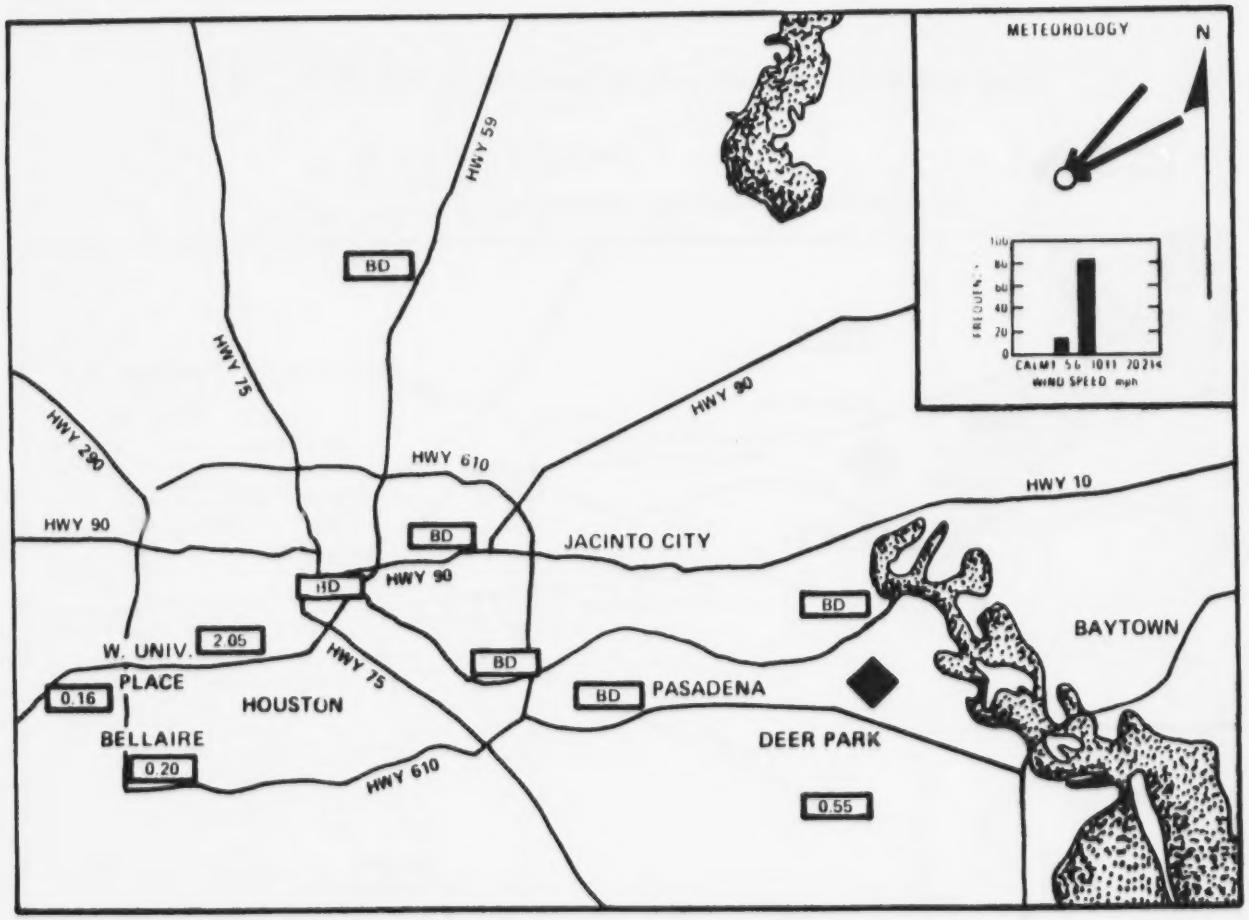


Figure 24. Ambient concentrations of perchloroethylene in Houston, Texas, Monday, 9/25/78.

the northeast sector (Sites 4 through 8) were at or below the detection limit. At the background site (Site 10) PERC concentrations were also below detectable throughout this 4-day period, indicating PERC concentration in air masses entering the study area from the north is minimal. Site 3, located in the immediate vicinity of an industrial-scale dry cleaner, was the only site at which measurable quantities of PERC were detected on each day of the study regardless of meteorological conditions.

DETROIT, MICHIGAN

A summary of the NWS data obtained from Detroit appears in Table 9. With the exception of the first 2 days, winds were generally light and variable with fair to poor mixing conditions throughout the sample collection period.

Table 10 presents the ambient concentrations of PERC found in samples collected in the Detroit area. Twelve of the one hundred samples fell below the detection limit of the method (0.10 ppb). The maximum observation was 2.16 ppb and the overall average was estimated (again, using one-half the detection limit for indeterminate samples) at 0.46 ppb.

Although the two highest average daily concentrations occurred on the second Friday and Saturday in the study period, this seeming anomaly may be explained by the very poor mixing conditions on those days (Table 9). Otherwise, the familiar pattern of higher mid-week PERC concentrations was maintained. All of the subdetectable samples were collected on a Friday, Saturday, or Sunday, and the minimum average concentration once again occurred on a Sunday.

The sampling site averages appear to be grouped into two fairly distinct classes. Sites 1 through 4, located in downtown Detroit, averaged approximately twice the levels observed in the less densely populated and industrialized suburbs (Sites 5 through 10). The minimum average concentration occurred at Site 8, the most rural sampling site location.

Daily plots showing the observed PERC concentrations and the corresponding distributions of wind direction and speed (monitored at Site 3) are shown in Figures 25 through 34. Again, excellent agreement exists between the meteorological measurements made by NWS and EPA.

The absence of well-defined point sources and sustained meteorological systems makes transport evaluation more difficult than was the case in the Houston study. However, it does appear that PERC concentrations in air masses moving from the southwest are at subdetectable levels prior to encountering sources which lie within the metropolitan area (e.g., 10/27/78 and 11/5/78). Also, relatively high ambient PERC concentrations are apparently attained under conditions of meteorological stagnation (e.g., 11/3/78 and 11/4/78).

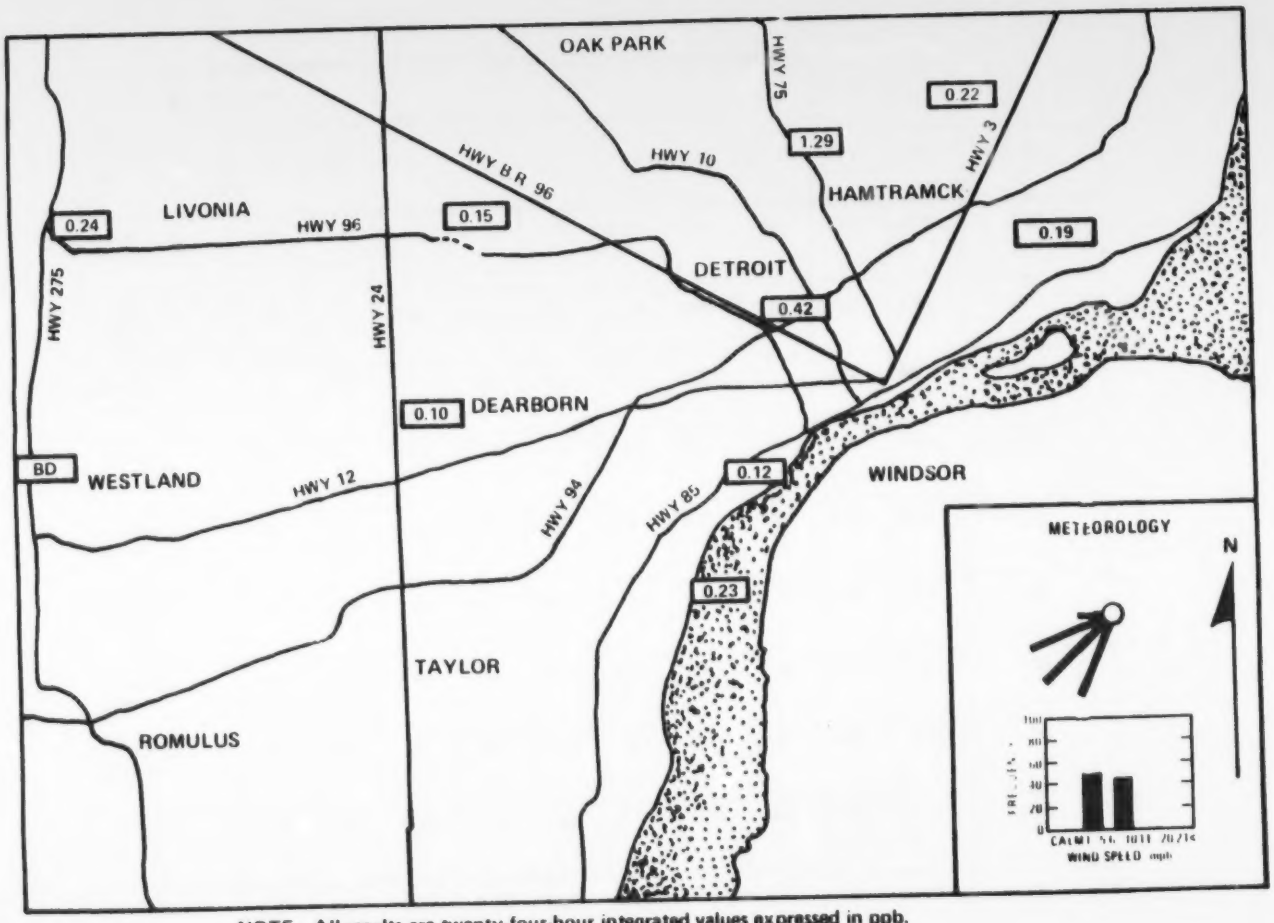
Table 9. NATIONAL WEATHER SERVICE DATA FROM DETROIT, MICHIGAN, 10/27/78 – 11/5/78

Date Oct:	Wind Direction	Time	Windspeed (KTS)	Temp. Min/Max (°F, °C)	Mixing	Comments
27	SW	ALL	8–20	40/59	G	
28	SW	01–05	8–10	38/54	G	
	NW–N	06–00	5–15			
29	N	01–10	2–5	18/32	F	
	E/Variable	11–15	0–5			
	E	16–00	3–8			
30	SE/Variable	01–10	0–4	36/63	F	
	S	11–00	5–12			
31	SW	01–09	0–8	41/61	F	Fog and haze in the morning
	N	10–14	8–10			
	NE/N	15–00	5–10			
Nov:						
1	N/Variable	01-13	0–4	35/55	F	
	SE	14–20	5–8			
	SW	21–00	4–8			
2	SW	01–12	8–12	41/67	F	
	W	13–20	5–10			
	Calm/Variable	21–00	0–3			
3	Calm	01–09	–	43/68	P	Fog and haze all day
	S	10–20	5–10			
	Variable	21–00	0–4			
4	SW/S	ALL	0–10	45/71	P	Fog and haze all day
	Variable					
5	S/SW	ALL	5–15	51/72	F	Fog and haze all day

Table 10. AMBIENT CONCENTRATIONS OF PERCHLOROETHYLENE IN DETROIT, MICHIGAN, 10/27/78 – 11/5/78

Date \ Site	1	2	3	4	5	6	7	8	9	10	Daily Average
Friday 10/27/78	0.22	0.19	1.29	0.42	0.12	0.15	0.10	BD	0.23	0.24	0.30
Saturday 10/28/78	0.36	0.20	0.37	0.31	0.29	0.26	0.23	BD	0.50	BD	0.26
Sunday 10/29/78	BD	BD	BD	BD	0.14	BD	0.13	BD	0.20	BD	0.08
Monday 10/30/78	0.58	0.37	0.45	0.66	0.11	0.42	0.53	0.18	0.18	0.27	0.38
Tuesday 10/31/78	2.16	0.59	1.10	0.64	0.47	0.33	0.46	0.20	0.45	0.29	0.67
Wednesday 11/1/78	0.80	0.73	0.85	1.00	0.75	0.47	0.42	0.23	0.59	0.32	0.62
Thursday 11/2/78	0.88	0.71	0.83	0.74	0.34	0.22	0.30	0.18	0.38	0.22	0.48
Friday 11/3/78	1.63	1.65	1.31	1.50	0.65	0.74	0.57	0.39	0.68	0.61	0.97
Saturday 11/4/78	1.26	0.61	0.96	1.03	0.69	0.49	0.40	0.33	0.35	0.68	0.68
Sunday 11/5/78	0.25	0.30	0.25	0.23	0.15	0.17	BD	BD	0.11	0.23	0.18
Site Average	0.82	0.54	0.75	0.66	0.37	0.33	0.32	0.17	0.37	0.30	0.46

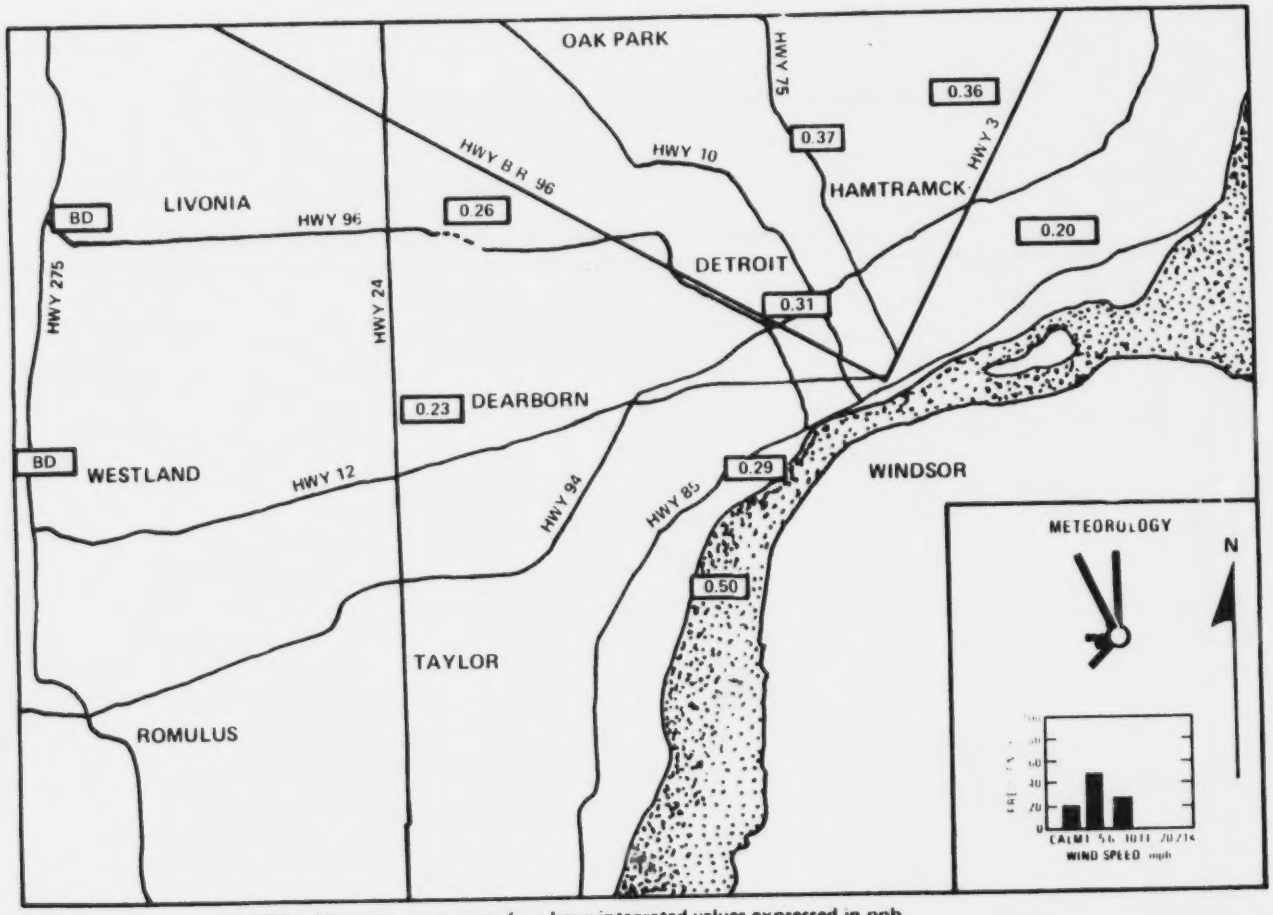
NOTE: All results are twenty-four-hour integrated values expressed in ppb.
ND= No Data
BD= Below Detectable (estimated at 0.05 ppb for computation of averages)



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

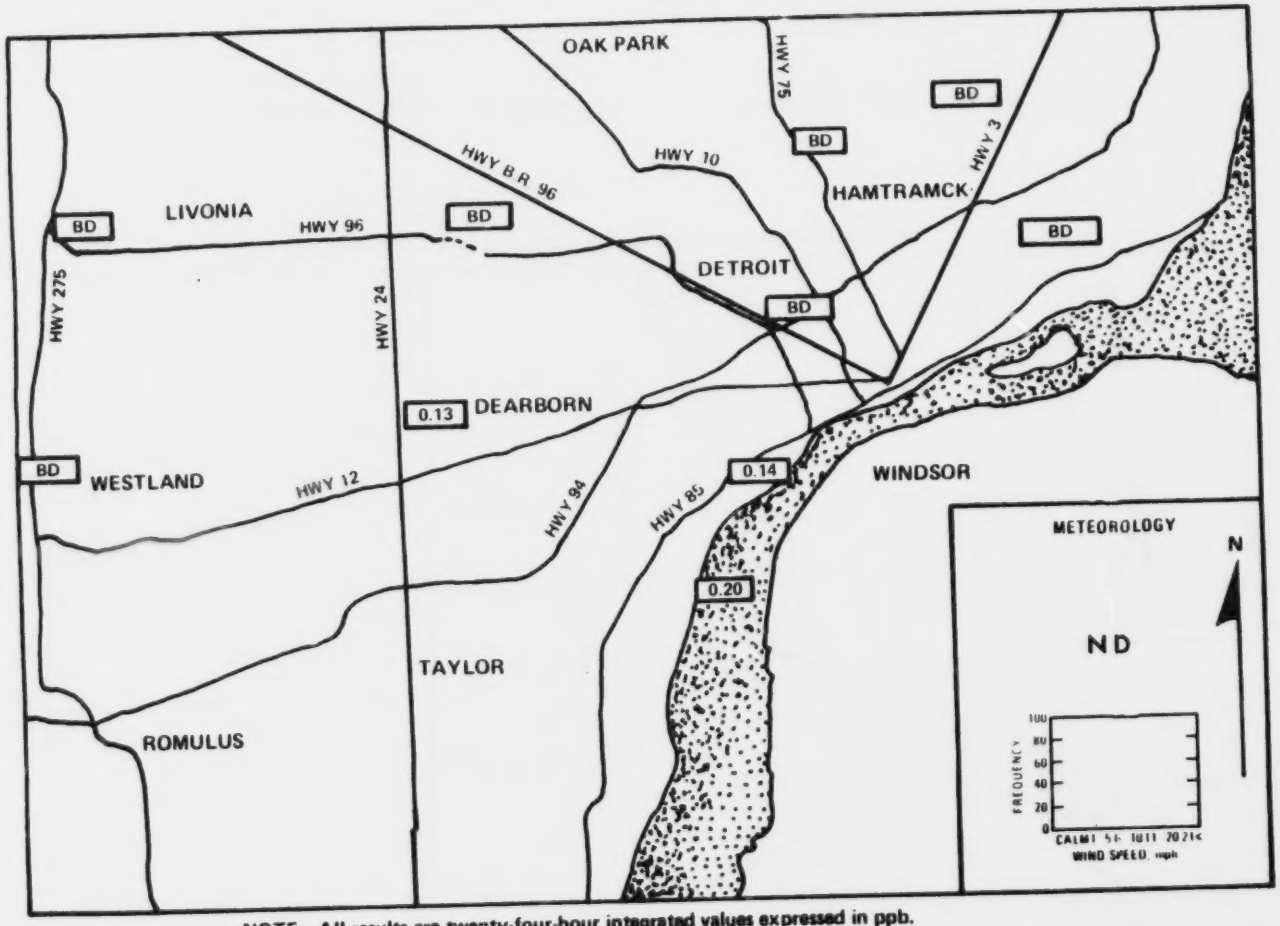
Figure 25. Ambient concentrations of perchloroethylene in Detroit, Michigan, Friday, 10/27/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

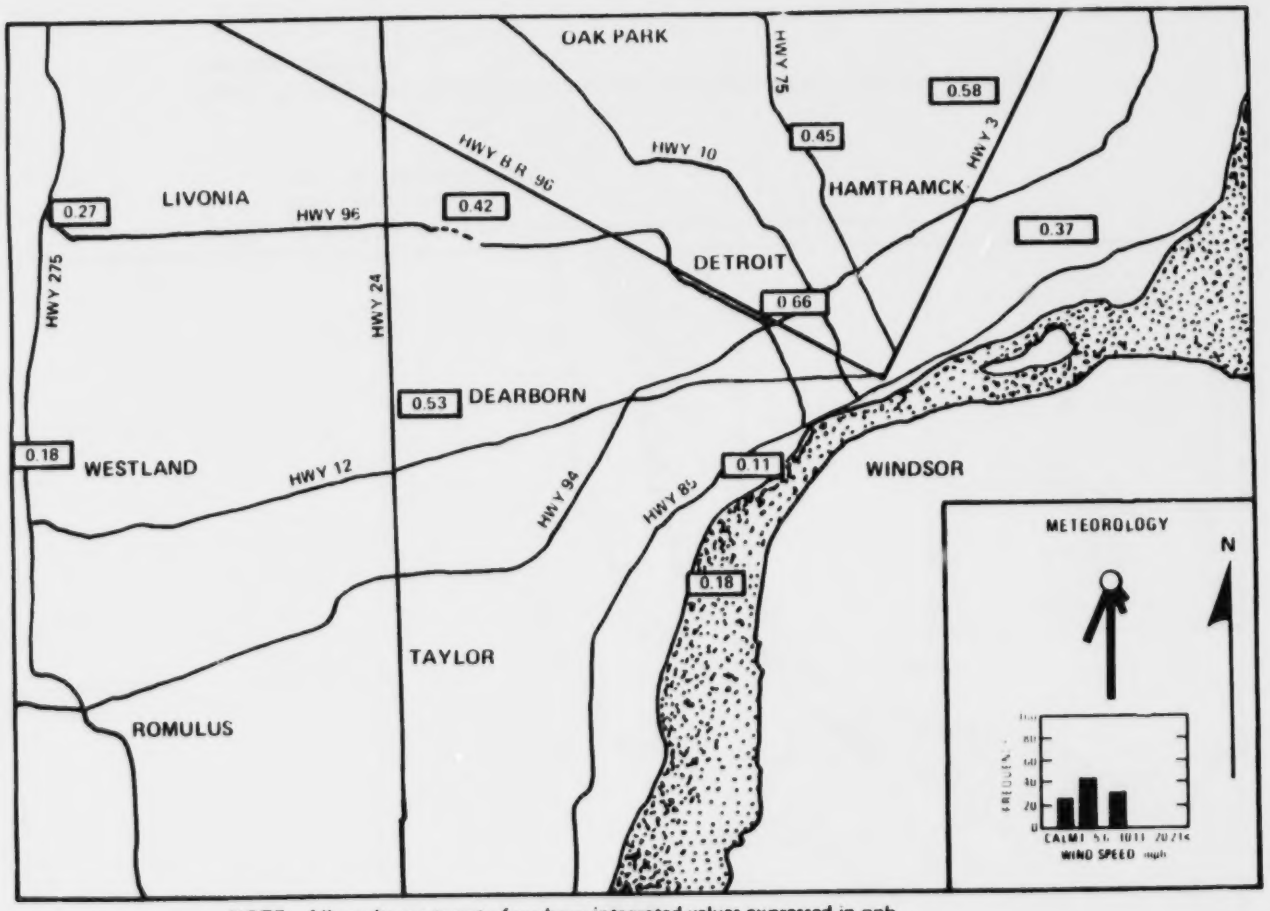
Figure 26. Ambient concentrations of perchloroethylene in Detroit, Michigan, Saturday, 10/28/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

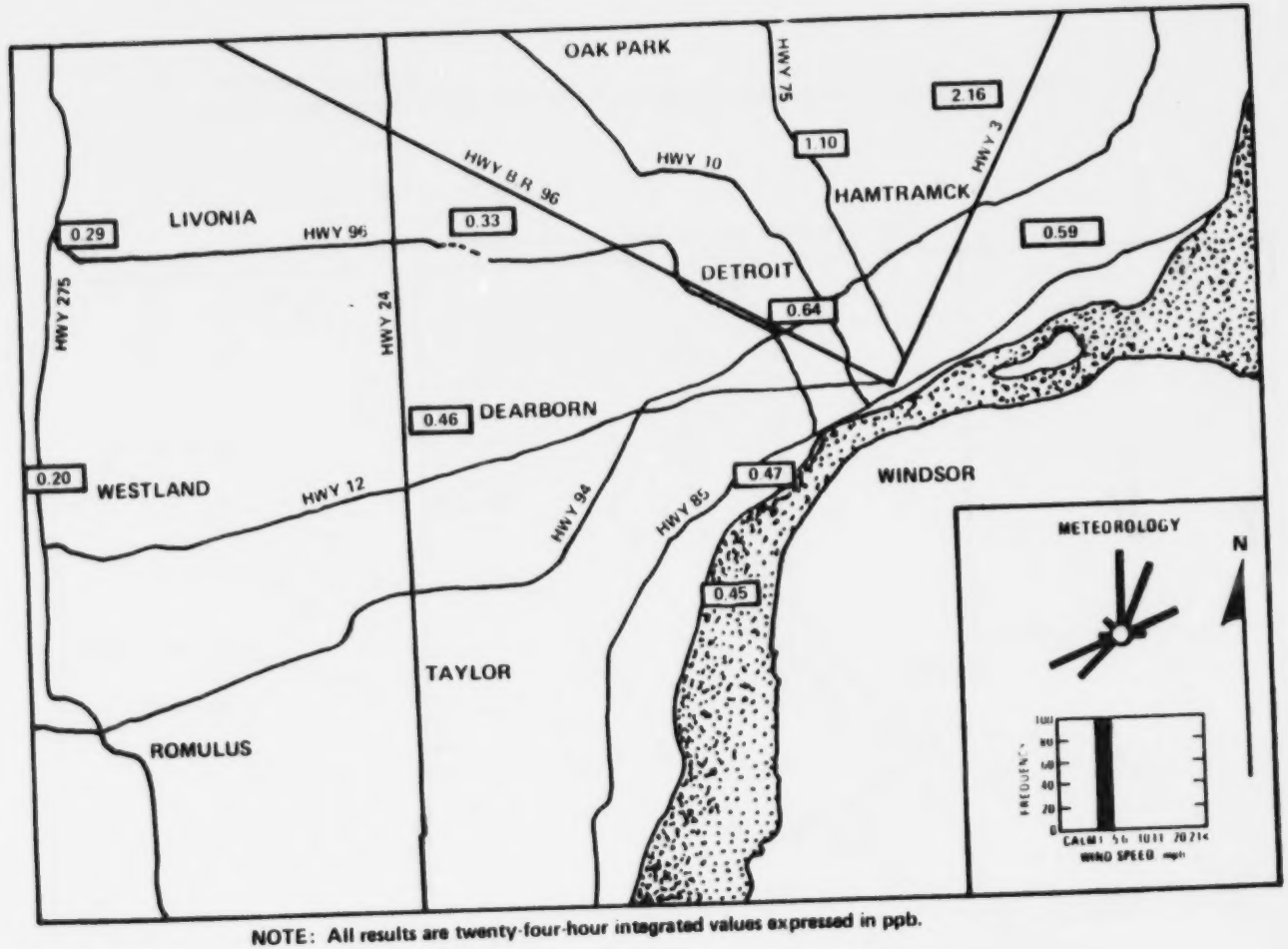
Figure 27. Ambient concentrations of perchloroethylene in Detroit, Michigan, Sunday, 10/29/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

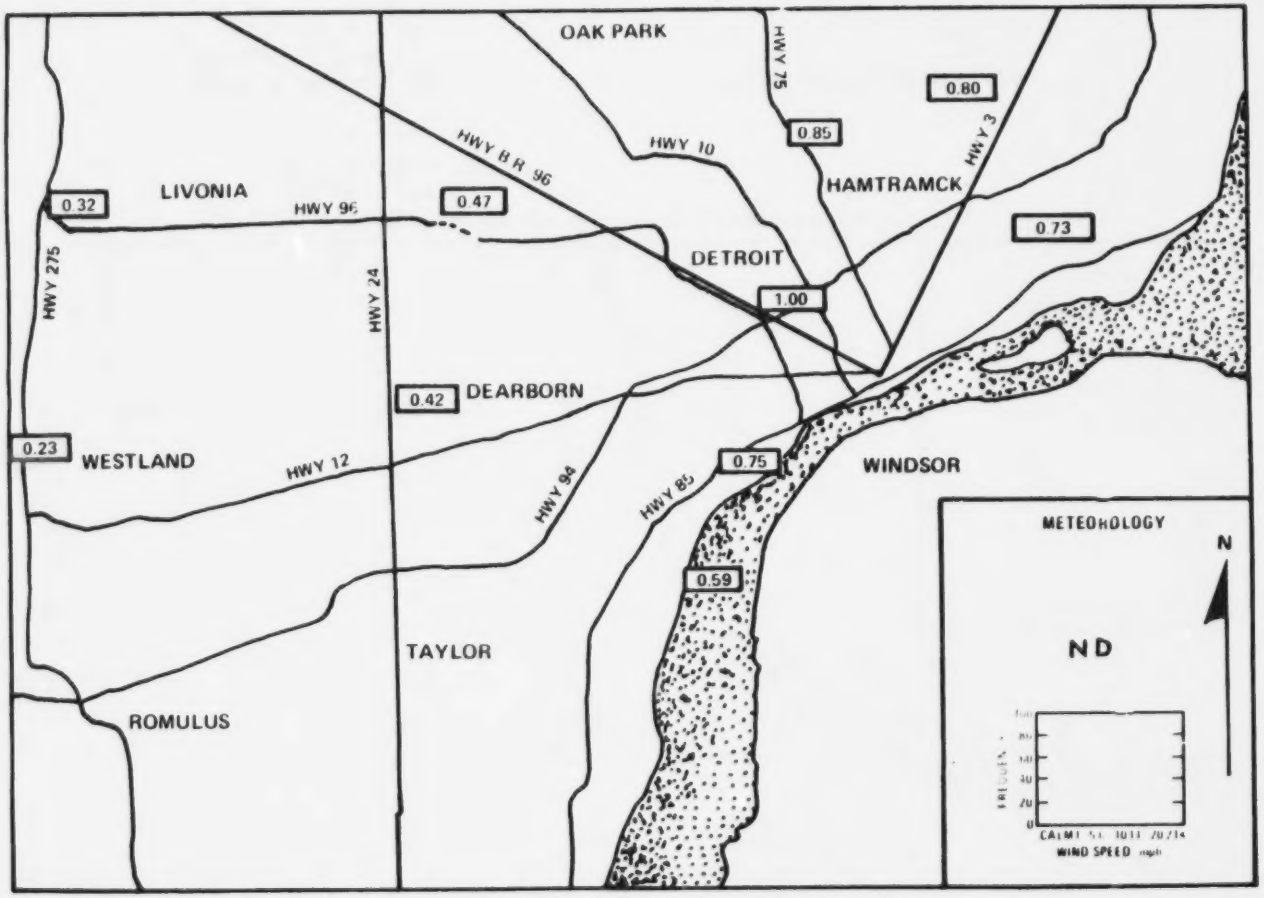
Figure 28. Ambient concentrations of perchloroethylene in Detroit, Michigan, Monday, 10/30/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

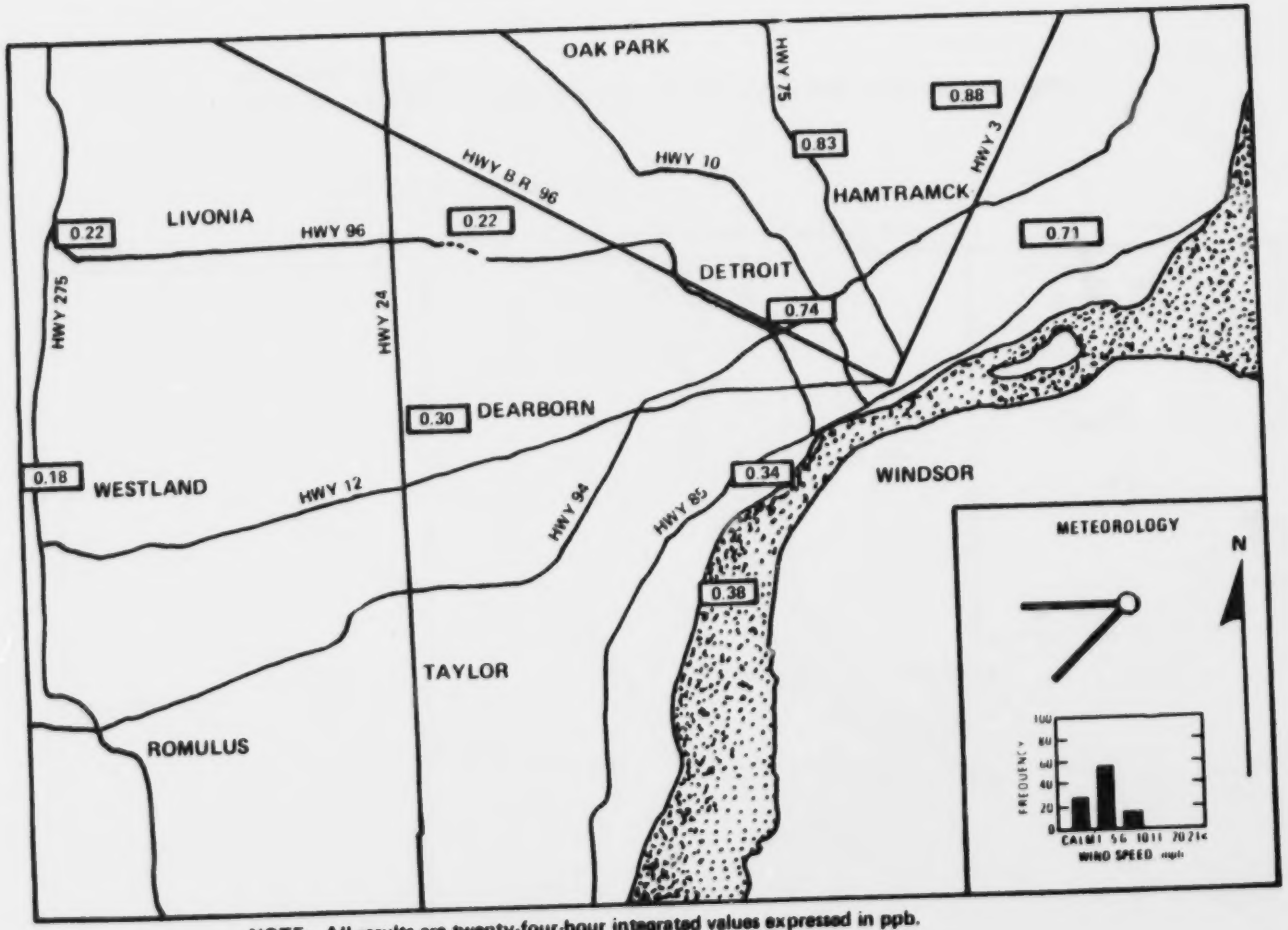
Figure 29. Ambient concentrations of perchloroethylene in Detroit, Michigan, Tuesday, 10/31/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

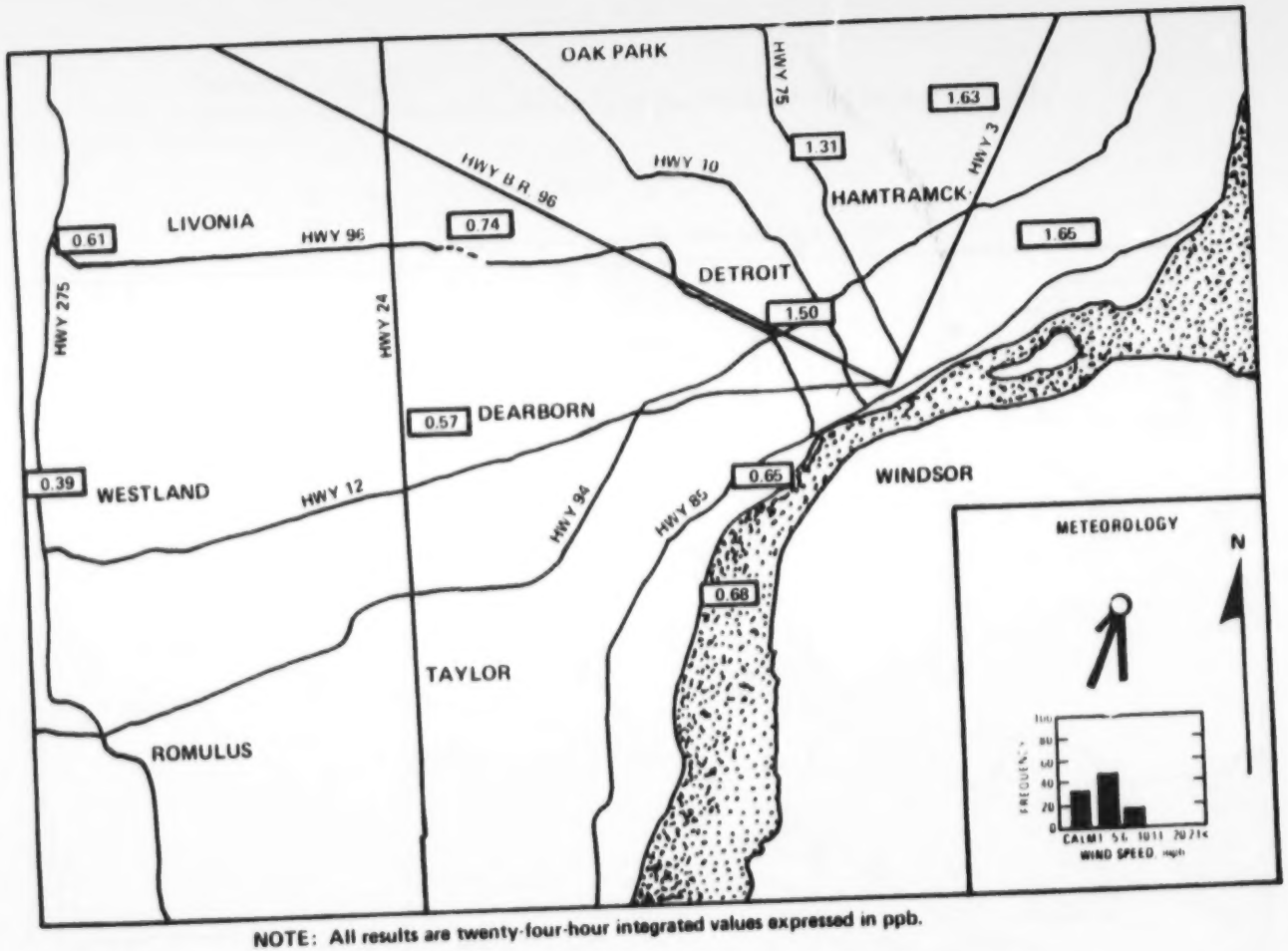
Figure 30. Ambient concentrations of perchloroethylene in Detroit, Michigan, Wednesday, 11/1/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

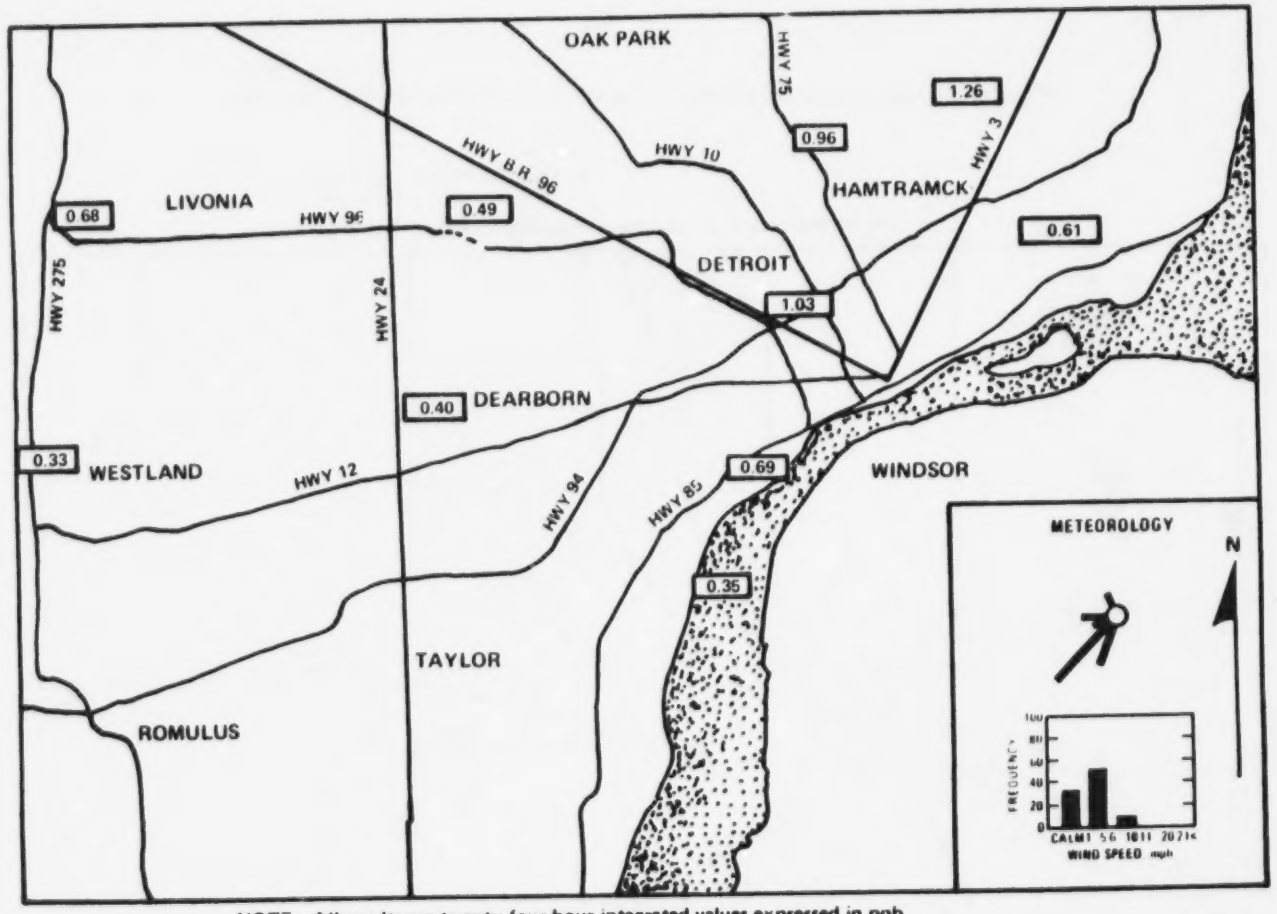
Figure 31. Ambient concentrations of perchloroethylene in Detroit, Michigan, Thursday, 11/2/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

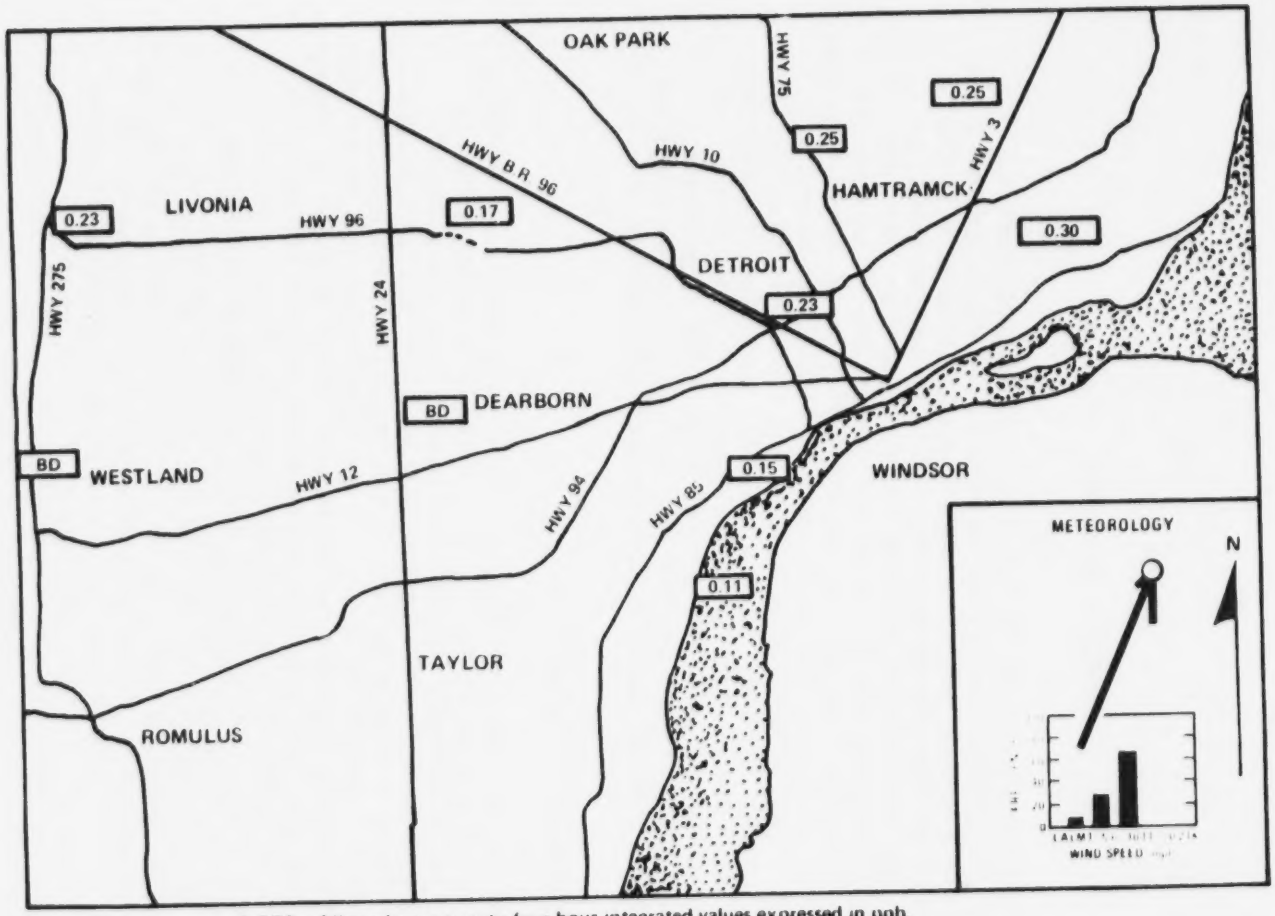
Figure 32. Ambient concentrations of perchloroethylene in Detroit, Michigan, Friday, 11/3/78.



NOTE: All results are twenty-four-hour integrated values expressed in ppb.

ND – NO DATA
BD – BELOW DETECTABLE

Figure 33. Ambient concentrations of perchloroethylene in Detroit, Michigan, Saturday, 11/4/78.



NOTE: All results are twenty-four hour integrated values expressed in ppb.

ND - NO DATA
BD - BELOW DETECTABLE

Figure 34. Ambient concentrations of perchloroethylene in Detroit, Michigan, Sunday, 11/5/78.

SECTION 5

QUALITY ASSURANCE

A quality assurance plan was initiated by QAB/EMSL/EPA combining (1) internal quality control procedures implemented by RTI to determine the precision of sample analysis, and (2) external quality assurance by QAB to provide information on measurement accuracy. Quality control checks on sampling methodology consisted of repeated checks of sampler flow rate during sample collection and collection of collocated samples at each site. Internal quality control procedures for the analytical measurements performed by RTI consisted of daily calibration of the analytical instrumentation, using standard solutions of perchloroethylene, and reanalysis of selected desorbed field samples. External quality assurance consisted of inserting with each day's field samples quality control samples of known perchloroethylene concentration. In addition, several blank field samples were analyzed and individual analyses of front and back sections were conducted for a portion of the charcoal tubes exposed in the field studies.

PRECISION OF THE ANALYTICAL TECHNIQUE

To determine the precision of the analytical technique (i.e., GC/ECD), 20 samples were reanalyzed after desorption and the results are shown in Table 11. Since the within-pair variability (measured by the standard deviation) appears to be an increasing function of level (measured by the average concentration), a simple pooling of the variance estimates is not valid for these data. Rather, least squares procedures were used to estimate an intercept and slope for standard deviation as a linear function of average concentration. The resulting intercept estimate was not significantly different from zero, so it may be safely assumed that the standard deviation (i.e., measurement error) is proportional to the average concentration (i.e., measurement level), at least within the range of these data (0.1-6.0 ppb). The constant of proportionality, called the "coefficient of variation" (CV = $(\sigma/\mu)100$), may be estimated as the slope of the linear relationship between standard deviation and average concentration with no intercept term. It is also possible to compute the variance of this parameter estimate so that a confidence interval about the true coefficient of variation may be constructed. As shown in Table 11, the estimated coefficient of variation for the analytical technique is 6.6 percent, with 95 prcent confidence that the true value falls between 4.9 and 8.3 percent. The precision of the desorption portion of the analytical procedures is more difficult to obtain and must be estimated from analysis of external quality control samples.

Table 11. REANALYSIS OF DESORBED SAMPLES

City	Sample	Run 1 (ppb)	Run 2 (ppb)
New York, NY	NY–007	BD	0.16
	NY–25	1.22	1.34
	NY–118	1.75	1.79
	NY–175	0.92	0.85
	NY–195	0.91	1.07
	NY–162	0.46	0.46
	NY–137	3.77	3.95
Houston, TX	QC–28	1.40	1.20
	H–354	0.14	0.14
	H–433	0.64	0.68
	H–458	3.19	3.00
	QC–38	5.84	5.12
Detroit, MI	D–3	BD	BD
	D–23	BD	BD
	D–45	BD	BD
	D–109	0.29	0.24
	D–131	0.32	0.33
	D–166	0.74	0.74
	D–204	0.25	0.22
	D–220	0.23	0.22

BD: Below Detectable

Coefficient of Variation: $CV = \left(\hat{\sigma} / \hat{\mu} \right) 100 = 6.6\%$

Confidence Interval: $\text{Prob}\ (4.9 \leqslant \left(\hat{\sigma} / \hat{\mu} \right) 100 \leqslant 8.3) = 95\%$

REPEATABILITY OF THE MEASUREMENT METHOD

The repeatability of the measurement method, combining sampling methodology and all analytical procedures, can be determined from analysis of collocated (i.e., duplicate) samples. Although duplicate samples were collected at each site each day, only a portion of these samples was analyzed. Table 12 shows the analysis for 28 pairs of duplicate samples from New York, Houston, and Detroit. The coefficient of variation of the measurement method, determined by the same procedure used to estimate analytical precision, is estimated at 16.2 percent, with 95 percent confidence of falling between 13.2 and 19.2 percent. Since, in addition to analytical imprecision, this estimate includes variability due to sample collection, handling, and desorption, an estimate of the combined relative variability which may be ascribed to these factors is obtained as:

$$\sqrt{CV^2_{Total} - CV^2_{Analytical}} = 14.8 \text{ percent}$$

EXTERNAL QUALITY ASSURANCE

Quality control samples were prepared by QAB using blank sample tubes filled with activated charcoal. These tubes were obtained from the same charcoal lot as were the field sample tubes. These tubes were exposed to known concentrations of perchloroethylene in a manner similar to that used to collect field samples.

A permeation tube filled with perchloroethylene and with a known output was used to generate the PERC necessary to spike the quality control tubes. A flow of nitrogen at 65 cm^3/min was passed over the permeation tube and then to a manifold. The tube to be spiked was connected to the manifold and the flow was allowed to pass through the tube for a specified time. The tube was then removed and capped. Tubes were checked at random to verify that the flow rate was constant through the system when the tube was on the manifold.

Standard Reference Materials (SRM's) for perchloroethylene are not available in the concentration range of interest (0.1 ppb to 10 ppb). It was necessary to verify that the permeation tube used to provide external quality control samples was generating the calculated perchloroethylene concentration. The permeation tube was first weighed on Cahn Model 100 Electrobalance which had been calibrated against NBS weights. Once the weight loss had been determined for the permeation tube, the tube and delivery systems were taken to a GC-Mass spectrometer operated by MACB/EMSL. Samples analyzed from the permeation system indicated that PERC was the only compound present within the sensitivity of the instrument. This analysis verifies the presence of perchloroethylene and that no impurities were present to account for any significant portion of the weight loss determined for the permeation tube.

To assess the accuracy of the analytical measurement method, one or two quality control samples were analyzed along with field samples on each

Table 12. ANALYSIS OF DUPLICATE FIELD SAMPLES

City	Sample Date	Site	Sample a (ppb)	Sample b (ppb)
New York, NY	8/18/78	6	2.13	3.06
	8/20/78	1	0.29	0.33
	8/21/78	9	0.29	0.31
	8/22/78*	6	10.61	3.92
	8/23/78	1	1.28	1.14
	8/23/78	4	1.29	0.97
	8/23/78	5	2.09	1.82
	8/24/78	2	1.33	1.37
	8/24/78	3	2.11	1.69
	8/25/78	10	0.35	0.49
Houston, TX	9/17/78	9	BD	BD
	9/19/78	10	0.27	0.17
	9/20/78	7	1.51	1.85
	9/21/78	4	0.43	0.41
	9/22/78	3	2.46	3.19
	9/23/78	9	BD	0.12
	9/24/78	1	BD	BD
	9/25/78	2	0.20	0.17
Detroit, MI	10/27/78	7	0.10	0.13
	10/28/78	9	0.50	0.50
	10/29/78	10	BD	BD
	10/30/78	5	0.11	0.14
	10/31/78	6	0.33	0.32
	11/1/78	3	0.85	0.93
	11/2/78	4	0.74	0.48
	11/3/78	8	0.39	0.46
	11/4/78	1	1.26	1.04
	11/5/78	2	0.30	0.27

* Omitted in computations

BD: Below Detectable

Coefficient of Variation: $CV = (\hat{\sigma}/\mu) 100 = 16.2\%$

Confidence Interval: $(13.2 \leq (\sigma/\mu) 100 \leq 19.2\%) = 95\%$

analysis day. Table 13 shows the analysis date for these samples, the quantity in µg thought to be loaded on the tube by QAB and the quantity found on the tube when analyzed by RTI. The percent recovery (%R = (amount found/amount loaded)100) is given in the last column. The overall percent recovery for 49 quality control samples analyzed from 8/25/78 to 11/27/78 was 70.2 percent, with a standard deviation of the mean of 1.7 percent.

The quality control results are shown stratified by spike level in Table 14. The following statistics appear for each level: sample size (µg), mean ($\bar{x}$), standard deviation (S), standard deviation of the mean ($S_{\bar{x}}$), bias (B), percent recovery (%R), and coefficient of variation (CV). With the exception of the lowest spike level (0.80 µg), it appears that percent recovery and coefficient of variation are essentially independent of level, with approximate values of 70 and 8 percent respectively. While it is not possible at present to determine whether perchloroethylene loss occurs in the adsorption as well as the desorption mechanism, it is believed that the latter accounts for most of the consistent thirty percent negative bias.

The coefficient of variation in this instance includes the variability in spiked sample preparation, desorption, and analytical determination. Recalling that the coefficient of variation for the latter factor alone has been estimated at 6.6 percent (Table 11), it appears that the variability introduced in the preparation of quality control samples and subsequent desorption is relatively minor. The lowest level of spiking included in the external quality assurance program approaches the minimum detectable limit for the measurement method (0.50 µg/tube is equivalent to a 24-hour sample collected at an ambient concentration of 0.20 ppb). Both accuracy and precision of the measurement method appear to deteriorate somewhat as this lower limit is approached.

Further external quality assurance procedures were performed by MACB/EMSL. First, two desorbed samples from the New York study were rerun in the EPA laboratory using the analytical method developed by RTI. The results (0.37 vs 0.43 ppb and 1.20 vs 1.27 ppb) suggest reasonably good interlaboratory reproducibility for the method. Secondly, to provide a completely independent field check on the total measurement system (sampling and analytical), several of the routine charcoal tube duplicates in the New York and Detroit field studies were replaced by tubes filled with Tenax (an alternative adsorbant). The Tenax tubes were analyzed for PERC by MACB using a different analytical scheme (i.e., a flash desorption followed by GC and mass spectroscopy (GC/MS). The comparative results as shown in Table 15 provide further substantiating evidence of the validity of the RTI values. These paired data are correlated with a coefficient of 0.82, with the average Tenax result exceeding the average charcoal result by 21 percent.

Finally, four desorbed field samples were supplied to PEDCo Environmental for species confirmation. Based on an analysis by GC/MS (Gregg Fusaro, PEDCo Environmental, Inc., personal communication), PEDCo confirmed the presence of perchloroethylene in each sample.

Table 13. ANALYSIS OF EXTERNAL QUALITY CONTROL SAMPLES

Analysis Date	Sample	μg Loaded	μg Found	% Recovery
8/25/78	QC–A	6.40	4.34	68
	QC–B	3.20	2.93	92
8/28/78	QC–C	1.60	1.32	83
	QC–D	8.00	5.42	68
9/29/78	QC–E	0.80	0.49	61
	QC–F	3.20	2.44	76
8/30/78	QC–G	8.00	5.86	73
8/31/78	QC–H	8.00	6.25	78
	QC–I	3.20	2.44	76
9/1/78	QC–J	3.20	2.44	76
	QC–K	1.60	1.46	91
9/5/78	QC–L	6.40	4.56	71
	QC–M	3.20	2.00	63
9/6/78	QC–N	3.20	2.27	71
	QC–O	3.20	1.67	52
10/2/78	QC–28	3.20	3.42	107
	QC–29	1.60	1.17	73
10/3/78	QC–28	4.80	3.51	73
	QC–29	1.60	1.17	73
10/4/78	QC–30	1.60	1.22	76
	QC–31	4.80	3.18	66
10/5/78	QC–32	0.80	0.67	84
	QC–33	8.00	5.25	66
10/6/78	QC–34	0.80	0.49	61
10/9/78	QC–35	8.00	5.60	70
	QC–36	1.60	1.07	67
10/11/78	QC–37	0.80	0.63	79
10/12/78	QC–38	8.00	5.52	69
	QC–39	1.60	1.16	73
10/13/78	QC–40	0.80	0.55	69
	QC–41	8.00	4.85	61
11/9/78	QC–42	0.80	0.33	41
11/10/78	QC–43	3.20	1.84	58
	QC–44	0.80	0.35	44
11/13/78	QC–45	8.00	4.94	62
	QC–46	8.00	5.43	68
	QC–50	4.80	3.54	74
11/14/78	QC–47	3.20	2.13	67
11/15/78	QC–48	1.60	1.25	78
	QC–49	1.60	1.29	81
11/16/78	QC–51	1.60	1.15	72
	QC–52	4.80	2.95	61
11/17/78	QC–53	4.80	3.12	65
11/20/78	QC–54	3.20	2.19	68
	QC–55	1.60	1.26	79
11/21/78	QC–56	3.20	2.56	80
	QC–57	7.80	3.57	46
11/22/78	QC -58	3.00	2.13	71
11/27/78	QC–59	7,80	4.64	59

Overall Recovery = 70.2 ± 1.7 percent

Table 14. ANALYSIS OF QUALITY CONTROL SAMPLES BY LEVEL

Loaded:	0.80 μg	1.60 μg	3.20 μg	4.80 μg	6.40 μg	8.00 μg
Found:	0.49 μg	1.32 μg	2.93 μg	3.51 μg	4.34 μg	5.42 μg
	0.67	1.46	2.44	3.18	4.56	5.86
	0.49	1.17	2.44	3.54		6.25
	0.63	1.17	2.44	2.95		5.25
	0.55	1.22	2.00	3.12		5.60
	0.33	1.07	2.27			5.52
	0.35	1.16	1.67			4.85
		1.25	3.42*			4.94
		1.29	1.84			5.43
		1.15	2.13			
		1.26	2.19			
			2.56			
n:	7	11	11	5	2	8
$\overline{X}$:	0.50	1.23	2.26	3.26	4.45	5.46
S:	0.13	0.10	0.35	0.26	0.16	0.43
$S_{\overline{X}}$:	0.05	0.03	0.11	0.11	0.11	0.14
$B=\overline{X}-\mu$	−0.30 μg	−0.37	−0.94	−1.54	−1.95	−2.54
$\%R=\frac{\overline{X}}{\mu} \times 100$:	62.5%	76.9%	70.6%	67.9%	69.5%	68.3%
$CV = \frac{S}{\overline{X}} \times 100$	26.0%	8.1%	15.5%	8.0%	3.6%	7.9%

* omitted in computations

Table 15. ANALYSIS OF TENAX FIELD SAMPLES

City	Sample Date	Site	Charcoal Result (ppb)	Tenax Result (ppb)
New York, NY	8/21/78	3	1.3	2.0
		7	0.5	1.5
	8/24/78	7	4.4	3.2
		8	1.7	3.3
		9	2.4	2.9
		10	1.1	1.8
Detroit, MI	10/28/78	4	0.3	0.4
	10/29/78	8	< 0.1	0.1
	10/30/78	6	0.4	0.5
	10/31/78	7	0.5	0.5
	11/1/78	9	0.6	0.7
	11/2/78	5	0.3	0.3
	11/3/78	3	1.3	1.1
Average			1.23	1.52

ASSESSMENT OF STATIC CONTAMINATION AND BREAKTHROUGH

As previously explained, the samplers employed in the field studies were controlled by a timer to operate on a midnight-to-midnight cycle. This sampling schedule required that a fresh charcoal tube be positioned in the standby mode for ~ 12 hours prior to the 24-hour sampling period and an additional 12 hours subsequent to this period. In an effort to simulate this static exposure, a charcoal tube with one end open was left for a 24-hour period at each monitoring site used in the field studies. These tubes were labeled as field blanks and returned to the analysis laboratory with the exposed field samples. A portion of the field blanks were analyzed and the results appear in Table 16. Since all results are below the minimum detectable limit, static contamination is not considered to occur to any significant extent.

The NIOSH charcoal tubes used for sample collection consist of two sections of activated charcoal separated by a section of urethane foam. The front section contains 100 mg charcoal while the back section contains 50 mg. In the analytical procedure followed, the charcoal from the two sections is mixed prior to desorption (Appendix A, Section 1.0). This procedure was waived, however, for about 10 percent of the field samples for which individual analytical determinations were made for the front and back sections of each tube. These results appear in Table 17.

The purpose of this special treatment was to determine whether or not appreciable quantities of perchloroethylene appeared in the back section of any field sample. Evidence of such perchloroethylene "breakthrough" would raise the possibility of sample loss and render the results unreliable. Of the 24 tubes analyzed individually, only one contained a detectable level of perchloroethylene in the back section. This particular sample was collected at the Greenpoint Treatment Plant in New York City on 8/22/78 and was the highest concentration observed in the field studies (10.61 ppb). Of note is that the duplicate for this sample was analyzed (Table 12), and the resultant concentration was a much lower value (3.92 ppb). The variability in this pair was not in the population of duplicate results and, hence, was not included in the statistical computations. This maximum value, then, must be considered questionable on the basis of the results of the quality assurance program.

ESTIMATION OF CONCENTRATION INTERVALS

The estimates of overall method repeatability and accuracy derived in the quality assurance program may be used to construct a confidence interval about the true value associated with any measured perchloroethylene concentration. Such an interval estimate consists of a lower and upper bound which will bracket the true concentration value for a preselected frequency (e.g., 95 percent) of trials.

Table 16. ANALYSIS OF CHARCOAL TUBE FIELD BLANKS

City	Sample Date	Site	Concentration (ppb)
New York, NY	8/18/78	3	< 0.10
	8/19/78	6	< 0.10
	8/21/78	6	< 0.10
Houston, TX	9/16/78	–	< 0.10
	9/18/78	1	< 0.10
	9/21/78	1	< 0.10
	9/23/78	1	< 0.10
Detroit, MI	10/28/78	7	< 0.10
	10/29/78	9	< 0.10
	10/30/78	10	< 0.10
	10/31/78	6	< 0.10
	11/01/78	5	< 0.10
	11/02/78	8	< 0.10
	11/04/78	2	< 0.10

Table 17. INDIVIDUAL ANALYSIS OF FRONT AND BACK CHARCOAL SECTIONS

City	Sample Date	Site	Front (ppb)	Back (ppb)
New York, NY	8/20/78	6	0.75	< 0.10
	8/22/78	6	10.40	0.21
	8/23/78	6	6.44	< 0.10
	8/24/78	6	4.27	< 0.10
	8/25/78	6	3.00	< 0.10
	8/26/78	6	4.10	< 0.10
Houston, TX	9/17/78	2	< 0.10	< 0.10
	9/18/78	7	2.37	< 0.10
	9/20/78	4	0.57	< 0.10
	9/20/78	7	1.85	< 0.10
	9/21/78	4	0.41	< 0.10
	9/22/78	3	3.19	< 0.10
	9/23/78	9	0.12	< 0.10
	9/24/78	10	< 0.10	< 0.10
	9/25/78	2	0.20	< 0.10
Detroit, MI	10/27/78	9	0.23	< 0.10
	10/28/78	9	0.50	< 0.10
	10/29/78	3	< 0.10	< 0.10
	10/30/78	5	0.14	< 0.10
	10/31/78	6	0.32	< 0.10
	11/1/78	3	0.93	< 0.10
	11/2/78	4	0.48	< 0.10
	11/3/78	8	0.46	< 0.10
	11/4/78	1	1.04	< 0.10

Approximate lower and upper confidence limits may be computed as follows:

$$X\left[\frac{1}{R} \pm t_{\alpha/2}(CV)\right]$$

where X = measured PERC concentration (ppb)

$t_{\alpha/2}$ = student's-t statistic (2.048 for α= 0.05 with 28 degrees of freedom)

R = method recovery expressed as a fraction (0.702)

CV = method coefficient of variation expressed as a fraction (0.162)

For example, to construct an interval estimate for the median PERC concentration observed in New York City (1.00 ppb),

$$(1.00)\left[\frac{1}{0.702} \pm 2.048\ (0.162)\right]$$

= [1.09 ppb, 1.76 ppb].

REFERENCES

1. Mitre Corporation, "Air Pollution Assessment of Tetrachloroethylene," February 1976.

2. U.S. Department of Commerce, "Statistical Abstract of the United States," 1970.

3. Rutgers University, "Atmospheric Freons and Halogenated Compounds," November 1976.

4. U.S. Environmental Protection Agency, "Study to Support New Source Performance Standards for the Dry Cleaning Industry," May 1976.

APPENDIX A

METHOD FOR THE DETERMINATION OF AMBIENT PERCHLOROETHYLENE

1.0 PRINCIPLE AND APPLICABILITY

1.1 Ambient PERC is adsorbed onto activated coconut shell charcoal. The PERC is then desorbed with 25 percent CS_2/methanol and analyzed by gas liquid chromatography using and ECD.

1.2 The method is applicable to 24-hour sampling in the vicinity of PERC sources and in areas where low levels are expected. The samples are collected and returned to the laboratory for analysis.

2.0 LOWER DETECTABLE LIMIT AND RANGE

2.1 The lower limit of detection is estimated to be 0.68 $\mu g/m^3$ (0.1 ppb) assuming a 360-liter air sample at 250 cm^3/min sampling rate. The range of the method is 0.68 to 68 $\mu g/m^3$ (0.1 - 10 ppb) and can be extended to higher values with shorter sampling periods or by dilution of desorbed samples.

3.0 INTERFERENCES

3.1 It must be emphasized that any compound which has the same retention time as perchloroethylene at the conditions described in this method would be a potential interference. For this reason, it is important that confirmation of perchloroethylene by GC/MS be obtained for a selected number of samples.

4.0 PRECISION AND ACCURACY

4.1 Quality control tubes were prepared by an independent laboratory (QAB-EPA) with a permeation device in the range of 0.8 µg - 8.0 µg (equivalent to 0.33 ppb - 3.27 ppb in a 360-liter air sample). Forty-nine tubes were analyzed with an overall sample recovery of 70 percent and a mean standard error of 2 percent.

4.2 Reanalysis of 20 desorbed samples in the range of 0.1 ppb - 5.84 ppb produced a coefficient of variation of 6.6 percent.

4.3 Analysis of 27 duplicate field samples in the range of <0.1 ppb - 3.2 ppb resulted in a coefficient of variation of 16 percent.

4.4 Analysis of 23 front and back tube sections (i.e., 100 mg and 50 mg, respectively) for breakthrough in the range of < 0.1 - 6.44 ppb showed less than the minimum detectable level (i.e., < 0.1 ppb) in back sections of all tubes.

4.5 Analysis of 14 charcoal tube field blanks showed less than the minimum detectable level of the method (i.e., < 0.1 ppb).

5.0 APPARATUS

5.1 Sampling

5.1.1 Charcoal Tubes--NIOSH standard 150-mg tubes available from SKC, Incorporated, Pittsburgh, Pennsylvania 15220.

5.1.2 Sampling Pump--A calibrated sampling pump whose flow can be determined accurately and will sample at least 1 liter per minute.

5.1.3 Air Flow Meter--Rotameter or other type of device for measuring air flow rate, 0 - 500 cm^3/minute.

5.1.4 Tubing--All tubing must be Teflon tubing.

5.1.5 Elapsed Time Meter--To determine period of sampling.

5.1.6 Timer--For automatic on/off operation of sampler.

5.1.7 Calibration Kit--Calibrated wet test meter or soap bubble flow meter for calibration of sampling pumps.

5.2 Analysis

5.2.1 Gas Chromatograph--With Electron Capture Detector (ECD)

5.2.2 A mechanical or electronic integrator to determine peak area and a recorder for a visual copy of the chromatogram.

5.2.3 Chromatographic Column--1.8-meter glass column, 2-mm i.d., packed with 0.1 percent SP-1000 on Carbopack C 80/100 mesh. The packing material is available from Supelco, Inc., Bellefone, Pennsylvania 16823.

5.2.4 Syringe--5.0 µℓ for GC injection and a 50 µℓ for preparing standards.

5.2.5 Pipets--1.0 mℓ Mohr, graduated in 0.1 mℓ.

5.2.6 Sample Vials and Crimper--2.0 mℓ vials with Teflon-lined caps.

5.2.7 Ultrasonic Cleaner--Used to desorb sample.

5.2.8 Volumetric Flasks--10.0 mℓs, 200 mℓs.

5.2.9 Miscellaneous Lab Supplies--Vial rack, pipette, bulb, triangular file, beakers.

6.0 REAGENTS

6.1 Sampling

6.1.1 Charcoal Tubes--Commercially available as discussed in Section 5.1.1.

6.2 Analysis

6.2.1 Five percent methane in argon for chromatographic carrier gas and a filter/dryer. Specify ECD Grade methane in argon.

6.3 Calibration

6.3.1 Tetrachloroethylene (perchloroethylene), ACS--Analytical reagent grade.

6.4 Sample Desorption

6.4.1 Carbon Disulfide, Baker "Analyzed"

6.4.2 Methanol, Burdick and Jackson, "distilled in glass"

7.0 PROCEDURE

7.1 Sampling

7.1.1 Sampler Location--Ideally, the charcoal tube should be located at a level high enough above ground to eliminate contact of the incoming air with vegetation or physical obstructions.

7.1.2 Twenty-four Hour Sampling

7.1.2.1 Immediately before sampling, the ends of the tube should be broken to provide an opening at least one-half the internal diameter of the tube.

7.1.2.2 The smaller section of charcoal (50 mg) is used as a back-up and should be positioned nearest the sampling pump.

7.1.2.3 The charcoal tube is connected to the sampling pump with an appropriate length of Teflon tubing.

7.1.2.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

7.1.2.5 The flow, time, and/or volume must be measured as accurately as possible at the initiation and termination of sampling.

7.1.2.6 The charcoal tubes should be sealed with the supplied plastic caps immediately after sampling.

7.1.2.7 One tube should be handled in the same manner as the sample tube, except that no air is sampled through this tube. This tube should be labeled as the field blank.

7.2 Storage of Samples

7.2.1 All samples are immediately stored in a freezer or in a container with dry ice.

7.3 Preparation of Samples

In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool and retainer wire is removed with the use of a short piece of wire with a hook on the end. Both sections are poured into a 2-mℓ vial and 1 mℓ of CS_2/methanol mixture is carefully pipetted into the vial. The cap is then crimped onto the vial. If breakthrough studies are being conducted, each section of charcoal is poured into separate vials and analyzed individually. If any detectable amount is found in the back half, then breakthrough has occurred and results are not reliable.

7.4 Desorption of Samples

Samples are placed in an ultrasonic cleaner with sufficient water to cover three-fourths of the vial. After 5 minutes the samples are set aside for 1 hour and occasionally agitated.

7.5 Daily Calibration of Gas Chromatograph

A standard curve is prepared each day by first injecting 1 μℓ of blank solvent, CS_2/methanol, before any samples are desorbed. A detectable quantity of perchloroethylene may be present in the CS_2, and this will be designated as the reagent blank. This amount should never be greater than the 0.1 ppb standard which is injected next. A 1.0 ppb and a 2.0 ppb standard is injected and the area counts of all of these are plotted versus concentration. A linear regression analysis of the data should produce a straight line with the intercept at the area counts of the blank (usually above zero area counts). The curve prepared in this manner corrects for any perchloroethylene found in the blank solvent, if it is constant. The correlation coefficient of the calibration equation should never be less than 0.997.

7.6 Injection Technique

The solvent flush technique is used to eliminate any blow back. The syringe is first flushed with methanol several times to wet the barrel and plunger. Two microliters of methanol are drawn into the syringe to increase

the accuracy and reproducibility of the injected sample volume. The needle is removed from the solvent, and the plunger pulled back about 0.5 μℓ to separate the solvent flush from the sample with a pocket of air to be used as a marker. The needle is then inserted through the desorption vial septum and immersed in the sample, or the standard solution. A 1.0 μℓ aliquot is withdrawn and measured from end to end in the syringe barrel. After the needle is removed from the sample and prior to injection, the plunger is pulled back a short distance to minimize evaporation of the sample from the tip of the needle. Duplicate injection of each sample and standard should be made.

7.7 Gas Chromatograph Conditions

- Carrier gas, 5 percent methane in argon: 37 cm^3/min
- Nickel 63 ECD temperature: 218°C
- Electron capture standing current: 0.5
- Oven temperature: 125°C
- All transfer lines should be at least 170°C
- Attenuation: 512

7.8 Preparation of Standards

Standards are prepared by injecting 15 μℓ of pure perchloroethylene into a 50 mℓ volumetric flask and bringing to volume with 25 percent CS_2/methanol. This is equivalent to a 200 ppb standard, or 490 μg/mℓ. This stock solution is then diluted to 20 ppb (49 μg/mℓ). The 20-ppb standard then is diluted to 2.0 ppb (4.9 μg/mℓ) and 1.0 ppb (2.44 μg/mℓ). The 1.0 ppb standard is then diluted to 0.1 ppb (0.244 μg/mℓ). The ppb concentrations were calculated assuming 24-hour sampling at 250 cm^3/min, or 360 liters. The dilutions are always prepared with 25 percent CS_2/methanol.

7.9 Electron Capture Standing Current Versus Pulse Frequency Curve

This procedure demonstrates the sensitivity of the detector and will indicate cell contamination. This should be conducted initially and if problems of sensitivity occur.

8.0 CALCULATIONS

8.1 Parts Per Billion Concentration of Sample

From the calibration curve, find the area counts obtained from the sample which corresponds to the ppb. This ppb concentration is assuming a 360-liter sample. If the sample volume differs from 360 liters, then corrections must be applied. For example, from the calibration curve a sample was found to contain 1.0 ppb, but the sample volume was only 300 liters. The same μg weight of pollutant is in less air volume; therefore, the concentration is actually higher.

$$\frac{360\ell}{300\ell} = 1.2$$

1 ppb x 1.2 = 1.2 ppb actual concentration

If the sample volume is greater than 360 liters, then the opposite is true.

8.2 Parts Per Billion

$$ppb = \frac{W}{V} \frac{RT}{Pm\ 10^9}$$

where R = 0.08205 liter-atm/mole °K
T = 2.98.16°K (25°C)
V = volume of air
P = 1 atm
m = 166 g/mole molecular weight of perchloroethylene

$$ppb = \frac{W\ (\mu g)}{m^3} \times \frac{0.08205 \ell\text{-atm/mole-°K} \times 298.16\ (°K)}{1\ (atm) \times 166\ (g/mole)}$$

$$1\ ppb = \frac{6.789\ \mu g}{m^3} \text{ or } \frac{6.789 \times 10^{-3}\ \mu g}{\ell}$$

$$\frac{6.789 \times 10^{-3}\ \mu g}{\ell} \times 360\ell = 2.44\ \mu g$$

9.0 QUALITY CONTROL

9.1 A multifaceted quality control program should be employed to insure the integrity of all perchloroethylene results. A calibration curve prepared every day insures that the GC system is functioning properly. In order to insure that the 25 percent CS_2/methanol solvent is not contaminated, every bottle of each reagent should be screened initially. Daily analysis of each mixture insures that it is also not contaminated. A valuable part of the quality control program is the analysis of charcoal tube samples that have been loaded with perchloroethylene by an independent laboratory using a permeation system. These quality control tubes should be analyzed at least once a day with a quality control chart being used to identify any outliers and indicate the need for corrective action. Other quality control procedures include analyzing duplicate samples, repeat injections, blanks, and front and back halves to check breakthrough.

10.0 DAILY RECORD OF FIELD OPERATIONS

All Daily Check Sheets (Figure A-1) are to be completed and signed by the field operator on a daily basis. Duplicate copies of the Daily Check Sheets must be made. One copy will be sent with the samples to Barry Martin, MD-76, EPA Annex, RTP, N. C. 27711. The second copy is to be retained by the field personnel and included in their trip report upon their return to RTP.

10.1 City - Name the city where the study is located.

10.2 Date(s) Sampled - The data the sample was collected.

10.3 Operator - The field operator should sign his name.

10.4 Temperature - Record maximum and minimum temperature if available. If not, record whatever temperature is available.

10.5 Relative Humidity - Record relative humidity.

10.6 Precipitation - Record if cloudy, clear, scattered showers, heavy rain, etc.

10.7 Barometric Pressure - Record barometric pressure.

10.8 Wind - Record calm, steady, or gusty wind conditions.

10.9 Note - Add any pertinent comments.

10.10 Site No. - Each site will be assigned a number.

10.11 Type Sampler - Single, duplicate, or tandem.

10.12 Tube No. - Serial number of sample cartridge.

10.13 Time Period - Hours sampled (12-12)

10.14 Elapsed Time Meter - Record the meter reading at the beginning and end of the sampling period.

10.15 Time Run, Min. - Subtract beginning meter reading from end meter reading.

10.16 Flow Checks - Check the flow at the beginning of the sampler period with a calibrated rotameter. Using calibration curve supplied with rotameter, record flow on data sheet. Repeat for middle (if any) and ending flow checks. NOTE: Flows are measured with cartridge in place.

10.17 Vacuum - Record pump operating vacuum.

10.18 Average Flow Rate - Average the beginning, middle, and ending flow rate, and enter on check sheet.

10.19 Total Volume Sampled - Multiply the Average Flow Data by the Time Ran.

CITY _____

Dates Sampled _____

Operator _____

TEMPERATURE - MIN _____ MAX _____

Relative Humidity _____

Precipitation _____

Cloud Conditions _____

BAROMETRIC PRESSURE _____

Wind _____

Note _____

SITE NO.	TYPE SAMPLER S/N	TUBE NO.	TIME PERIOD	ELAPSED TIME METER BEGIN	ELAPSED TIME METER END	TIME RUN MINUTES	FLOW CHECKS CM^3/MIN BEGIN	FLOW CHECKS CM^3/MIN MID	FLOW CHECKS CM^3/MIN END	VACUUM READING	AVG. FLOW RATE CM^3/MIN	TOTAL VOLUME CM^3

Figure A - 1. Daily check sheet for 1978 PERC study conducted by EPA,RTP.

APPENDIX B

METEOROLOGICAL DATA SUMMARY

TABLE B-1. METEOROLOGICAL DATA, 8/18/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	330	08	76	60	3.5	82
02	360	07	75	120	3.5	81
03	350	07	73	150	5.0	79
04	320	06	72	150	4.0	78
05	340	10	72	130	4.0	76
06	330	08	71	130	5.5	76
07	330	11	72	150	6.0	75
08	350	10	74	150	6.0	75
09	330	09	76	160	7.0	76
10	320	10	77	150	8.0	77
11	360	08	78	120	7.5	80
12	340	10	79	130	6.5	82
13	310	07	81	130	6.0	86
14	310	08	81	140	6.0	88
15	360	09	81	150	5.0	90
16	010	08	81	140	6.0	90
17	320	12	81	140	7.5	90
18	310	08	80	140	6.0	90
19	340	07	77	100	6.5	88
20	360	05	78	110	5.0	87
21	360	05	76	120	4.5	84
22	040	08	76	110	2.5	82
23	050	10	73	120	4.0	82
24	050	08	72	150	5.0	81

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-2. METEOROLOGICAL DATA, 8/19/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	030	05	72	170	4.0	79
02	070	05	72	180	4.0	78
03	060	07	70	180	3.5	76
04	040	06	68	190	2.0	75
05	310	04	68	190	2.0	75
06	030	05	69	190	1.0	72
07	010	05	72	190	2.0	71
08	010	06	75	200	2.0	72
09	040	04	77	180	2.5	75
10	330	07	79	130	2.5	81
11	320	06	80	100	3.0	85
12	330	08	82	70	4.0	87
13	300	04	84	90	4.5	88
14	060	05	85	70	4.0	93
15	020	07	88	90	3.5	96
16	140	10	85	110	3.0	97
17	170	09	82	330	8.0	93
18	180	11	79	300	10.0	85
19	210	16	77	330	9.0	81
20	200	14	77	330	10.0	81
21	200	12	76	330	9.5	79
22	190	11	77	330	7.0	78
23	200	09	76	340	6.0	78
24	210	08	76	330	5.5	78

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-3. METEOROLOGICAL DATA, 8/20/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	140	07	76	340	4.0	78
02	170	08	76	330	3.0	78
03	170	17	75	330	3.5	78
04	180	06	75	300	3.5	78
05	210	06	75	350	3.0	78
06	270	07	76	350	2.5	78
07	300	07	76	340	2.5	78
08	310	09	79	60	3.0	78
09	330	10	81	100	5.0	80
10	360	11	80	140	7.0	82
11	360	14	79	150	6.5	85
12	350	11	77	130	7.5	83
13	330	14	78	130	9.0	81
14	340	14	78	120	10.0	80
15	340	11	79	130	8.0	82
16	350	10	80	130	7.0	82
17	360	09	81	140	6.0	85
18	360	09	79	140	5.0	88
19	360	10	79	140	6.0	87
20	010	14	78	150	6.0	85
21	010	13	75	140	5.0	83
22	360	16	74	150	7.5	82
23	020	14	72	150	8.5	79
24	010	13	71	150	8.5	78

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-4. METEOROLOGICAL DATA, 8/21/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	020	12	71	170	8.0	75
02	360	09	69	170	9.0	73
03	020	13	67	170	7.5	71
04	360	11	66	160	7.0	71
05	010	14	66	160	6.5	70
06	010	12	65	160	6.5	69
07	030	12	66	150	6.0	68
08	360	10	68	150	6.5	68
09	040	13	71	150	6.0	70
10	060	14	75	160	6.5	72
11	060	12	76	160	6.5	75
12	050	13	78	170	6.0	80
13	060	10	79	150	5.5	82
14	050	10	80	150	5.5	84
15	050	11	79	150	4.5	86
16	060	10	79	150	5.0	87
17	040	05	79	110	4.0	87
18	070	07	78	160	4.5	87
19	050	07	74	160	4.5	87
20	160	07	74	150	4.0	83
21	200	07	73	220	4.5	79
22	130	05	72	300	5.0	75
23	280	05	72	300	4.0	75
24	030	06	68	330	3.0	73

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-5. METEOROLOGICAL DATA, 8/22/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	360	05	68	190	2.0	72
02	020	06	66	170	1.5	71
03	010	05	66	140	2.5	70
04	330	07	66	160	2.5	70
05	330	05	65	160	2.0	69
06	360	04	66	150	3.5	60
07	010	05	68	150	4.0	69
08	040	06	72	140	3.5	69
09	060	07	74	160	3.0	71
10	040	07	76	160	3.5	75
11	040	06	78	210	3.5	81
12	030	07	80	210	2.5	85
13	320	07	80	90	5.0	86
14	050	05	81	90	4.5	86
15	010	05	82	120	4.0	90
16	270	08	82	130	3.5	92
17	180	08	80	90	5.0	91
18	170	09	77	120	4.0	91
19	170	06	76	300	7.5	86
20	170	08	75	300	8.0	80
21	190	08	74	300	5.5	78
22	200	10	73	330	6.0	78
23	210	08	72	45	4.5	77
24	220	07	71	45	4.5	75

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-6. METEOROLOGICAL DATA, 8/23/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	220	07	70	45	3.5	75
02	220	05	69	45	3.5	74
03	240	05	69	45	3.0	73
04	280	07	68	45	3.0	72
05	280	08	67	60	3.0	71
06	300	08	68	100	2.0	71
07	300	06	70	120	1.5	69
08	340	06	75	110	1.5	69
09	310	05	78	100	1.5	75
10	320	10	79	150	3.5	81
11	300	08	81	150	4.5	86
12	320	10	83	150	5.0	88
13	290	07	84	150	4.5	90
14	320	05	84	110	5.5	91
15	330	05	85	90	5.0	93
16	330	07	85	100	5.0	96
17	280	07	85	90	5.5	97
18	270	08	83	90	5.0	95
19	270	05	81	110	5.0	93
20	270	09	80	70	5.0	90
21	260	06	79	60	4.0	87
22	240	07	79	60	4.5	85
23	300	08	76	60	4.0	84
24	250	03	75	60	2.5	82

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-7. METEOROLOGICAL DATA, 8/24/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	290	04	74	45	3.0	81
02	300	07	74	Calm	Calm	79
03	280	07	73	45	2.5	78
04	230	05	72	Calm	Calm	77
05	280	03	72	Calm	Calm	76
06	260	06	72	30	2.0	76
07	000	00	74	45	2.5	75
08	230	07	78	30	2.0	74
09	230	09	81	30	3.5	78
10	250	08	82	30	5.5	81
11	290	10	83	45	6.5	85
12	310	09	84	30	5.5	88
13	250	08	85	30	7.0	90
14	250	11	86	30	7.5	92
15	230	09	86	30	7.0	92
16	250	10	86	30	7.5	92
17	280	10	85	30	6.5	92
18	270	10	84	45	5.5	91
19	260	08	82	30	5.5	90
20	250	09	82	45	4.5	88
21	050	11	77	45	4.5	87
22	040	12	74	45	3.5	86
23	040	12	72	90	3.0	83
24	050	14	71	180	7.0	77

TABLE B-8. METEOROLOGICAL DATA, 8/25/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	050	14	70	180	6.0	73
02	060	17	67	180	7.0	72
03	060	15	65	180	8.0	70
04	050	15	64	180	7.0	68
05	040	17	64	180	7.0	67
06	050	15	63	180	7.0	65
07	050	14	64	180	7.5	65
08	040	12	62	180	7.5	65
09	050	13	63	180	6.5	65
10	060	15	64	180	6.0	64
11	050	14	63	180	7.0	63
12	060	12	62	180	6.0	64
13	050	15	62	180	6.0	63
14	050	12	62	180	7.0	62
15	020	11	62	180	6.0	62
16	020	12	61	180	5.5	62
17	050	13	61	180	5.0	62
18	050	09	61	180	5.0	61
19	010	08	61	180	4.5	61
20	030	11	61	180	4.5	61
21	010	12	61	180	3.5	61
22	020	06	61	180	4.0	61
23	020	07	61	180	3.5	61
24	020	06	61	160	3.5	61

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-9. METEOROLOGICAL DATA, 8/26/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	010	05	61	170	3.0	61
02	010	06	61	190	2.0	62
03	010	06	62	180	2.0	62
04	010	04	62	180	2.5	62
05	310	06	62	170	2.5	62
06	320	07	62	Calm	Calm	62
07	360	07	62	70	2.5	62
08	360	08	63	150	3.0	65
09	010	07	65	160	3.5	67
10	070	05	68	150	4.0	69
11	050	07	68	170	3.5	73
12	040	09	71	170	3.5	77
13	080	09	72	170	4.0	79
14	050	08	73	180	4.5	80
15	070	07	76	150	5.5	81
16	060	08	76	180	3.5	86
17	060	05	75	150	4.0	88
18	150	07	73	200	3.0	86
19	180	09	73	300	6.5	78
20	180	10	70	300	7.0	75
21	190	11	70	300	6.5	73
22	210	09	69	310	6.0	71
23	220	07	69	330	5.5	71
24	230	10	69	330	4.5	70

*These data are taken from NWS hourly observations and supplied by the National Climatic Center.

TABLE B-10. METEOROLOGICAL DATA, 8/27/78

NWS* DATA - LA GUARDIA AIRPORT, NEW YORK, NY				EPA DATA - SITE 6 - NEW YORK, NY		
Hour	Wind Direction (°)	Wind Speed (kts)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	230	09	68	45	4.5	70
02	230	05	68	30	4.5	70
03	240	07	67	30	5.0	70
04	240	05	66	45	4.0	69
05	250	04	67	60	5.0	69
06	250	04	66	60	4.5	68
07	330	06	67	45	2.0	68
08	040	07	70	90	3.0	68
09	060	08	73	160	3.0	70
10	060	10	75	180	2.5	73
11	040	09	77	210	2.5	79
12	030	08	78	210	3.5	84
13	060	09	80	180	3.0	87
14	060	09	80	150	2.5	90
15	170	09	78	300	7.5	87
16	140	09	78	300	8.0	81
17	150	13	75	300	8.0	80
18	180	13	76	300	9.0	78
19	170	09	74	310	8.0	76
20	170	07	75	300	7.0	75
21	170	11	74	300	7.5	75
22	170	12	74	300	8.0	75
23	170	12	74	330	6.5	76
24	180	10	74	330	5.5	76

*These data are taken from NSW hourly observations and supplied by the National Climatic Center.

TABLE B-11. EPA METEOROLOGICAL DATA, SITE 8, HOUSTON, TEXAS

Date	9/16/78			9/17/78			9/18/78			9/19/78			9/20/78		
Hour	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	160	3.0	78	160	4.0	80	150	4.5	81	150	5.5	82	160	2.0	80
02	150	2.5	78	160	3.5	79	150	4.0	80	150	5.0	81	Calm	Calm	80
03	160	3.0	78	160	3.0	79	160	5.0	80	150	4.0	81	Calm	Calm	80
04	150	2.5	78	160	3.0	78	170	5.5	80	150	3.5	80	Calm	Calm	80
05	160	2.5	78	160	3.5	78	170	5.0	80	150	3.5	80	Calm	Calm	80
06	180	2.5	78	150	2.5	78	160	3.5	80	160	3.5	80	60	3.5	79
07	190	2.0	77	150	2.0	78	150	3.5	80	150	3.0	80	50	3.5	79
08	180	2.5	78	150	2.0	78	150	2.5	80	160	2.5	83	60	5.5	80
09	160	2.5	79	160	2.5	82	160	3.5	83	160	3.0	88	90	4.0	82
10	180	3.5	81	170	5.5	87	170	5.5	87	170	5.0	90	45	3.5	84
11	210	5.5	85	180	6.5	87	180	7.5	89	160	6.5	93	100	3.5	80
12	210	5.0	91	160	6.5	92	180	8.0	92	160	6.5	97	180	4.0	82
13	210	4.5	95	180	8.0	95	180	8.5	93	160	7.0	96	160	5.0	87
14	220	3.5	97	180	8.5	95	180	8.0	95	180	7.5	95	150	4.0	90
15	180	4.0	97	160	10.0	95	180	8.0	97	180	8.0	95	150	4.0	90
16	160	5.0	93	160	10.0	94	170	8.0	97	180	8.5	95	150	4.5	84
17	130	5.5	88	160	10.0	92	160	8.5	95	180	7.0	94	220	5.0	82
18	120	8.0	91	180	9.0	92	150	8.5	91	180	7.5	91	220	3.5	81
19	160	8.0	90	180	9.0	90	160	7.5	90	160	6.5	90	210	4.0	81
20	160	7.0	87	170	7.5	87	160	6.0	88	160	4.5	87	180	2.5	81
21	160	6.0	85	160	6.5	85	160	5.5	85	150	4.0	84	200	1.5	80
22	180	5.0	82	150	5.0	83	160	5.5	84	150	3.5	82	Calm	Calm	80
23	160	4.0	81	150	5.0	82	150	5.0	83	170	3.0	81	Calm	Calm	80
24	160	3.5	80	150	4.5	81	150	5.5	82	160	2.0	80	Calm	Calm	80

TABLE B-12. EPA METEOROLOGICAL DATA, SITE 8, HOUSTON, TEXAS

Date	9/21/78			9/22/78			9/23/78			9/24/78			9/25/78		
Hour	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	160	2.0	80	60	3.5	80	45	9.0	78	70	7.0	80	45	7.0	73
02	150	2.0	80	60	4.0	80	60	8.0	76	70	6.5	80	45	8.0	72
03	Calm	Calm	80	50	3.5	79	60	7.0	75	80	7.5	79	45	5.5	70
04	Calm	Calm	79	30	4.5	78	60	8.0	75	80	7.0	78	60	6.0	70
05	Calm	Calm	78	30	5.5	78	60	6.5	75	80	8.0	78	60	5.5	68
06	60	2.0	78	30	5.5	78	60	6.5	74	80	6.5	78	60	6.0	68
07	70	3.0	78	30	6.5	78	60	7.0	73	80	6.5	76	60	5.5	68
08	80	3.0	78	30	5.5	75	60	8.0	72	70	6.5	75	80	5.0	68
09	80	4.0	80	30	6.0	77	60	8.0	71	60	8.5	74	70	5.0	69
10	80	4.0	82	30	7.0	78	60	8.0	72	80	7.5	75	60	6.0	71
11	80	6.0	86	40	6.5	82	60	8.0	73	70	7.5	78	60	5.0	76
12	80	6.0	87	40	8.0	87	60	7.5	75	60	8.5	80	70	6.0	80
13	60	6.0	85	40	9.0	88	70	7.0	77	60	8.0	81	60	7.0	81
14	190	5.0	78	60	10.5	90	80	7.0	80	60	9.0	83	45	6.5	82
15	180	2.5	85	70	10.0	91	80	6.0	82	45	8.5	87	30	6.0	86
16	100	7.0	86	60	8.5	90	70	5.0	85	45	9.0	88	45	7.0	86
17	70	6.5	85	90	6.5	81	60	6.0	86	45	7.0	86	45	6.5	87
18	120	6.5	89	100	7.0	92	90	4.5	88	30	6.5	86	45	6.5	87
19	120	5.5	87	150	6.5	91	90	3.5	87	30	6.5	84	30	6.5	86
20	120	3.5	87	60	7.0	87	90	3.0	85	45	6.5	81	45	4.5	83
21	80	2.5	86	45	8.5	85	90	2.5	83	45	6.0	79	45	6.0	81
22	80	4.0	82	45	8.0	82	70	3.5	82	60	7.5	78	60	6.0	80
23	70	3.0	81	45	9.0	80	70	4.0	81	45	6.5	75	60	7.0	78
24	60	4.0	81	45	8.0	78	70	4.0	81	45	7.0	73	45	7.0	78

TABLE B-13. EPA METEOROLOGICAL DATA, SITE 3, DETROIT, MICHIGAN

Date	10/27/78			10/28/78			10/29/78			10/30/78			10/31/78		
Hour	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	270	5.0	40	230	4.0	48	Calm	Calm	37	Calm	Calm	35	230	4.0	56
02	270	5.0	38	230	5.0	48	Calm	Calm	35	Calm	Calm	34	230	4.0	53
03	240	4.0	37	270	4.0	48	Calm	Calm	33	130	2.0	36	250	3.0	50
04	225	4.0	36	230	3.0	45	Void	Void	Void	Calm	Calm	36	240	3.0	49
05	225	4.0	36	240	2.0	44	Void	Void	Void	Calm	Calm	37	240	3.0	48
06	225	4.0	36	270	2.0	42	Void	Void	Void	Calm	Calm	37	240	2.0	48
07	240	4.0	36	330	2.0	42	Void	Void	Void	Calm	Calm	38	250	3.0	47
08	225	4.0	37	330	2.0	42	Void	Void	Void	150	2.0	39	270	3.0	47
09	210	6.0	38	330	3.0	41	Void	Void	Void	150	5.0	44	250	3.0	50
10	210	6.0	40	330	4.0	40	Void	Void	Void	180	7.0	49	345	4.0	56
11	210	6.0	45	360	5.0	44	Void	Void	Void	180	8.0	51	360	3.0	59
12	210	8.0	50	360	8.0	48	Void	Void	Void	180	8.0	56	30	4.0	60
13	240	9.0	52	330	8.0	50	Void	Void	Void	180	6.0	59	360	4.0	60
14	240	9.0	55	330	7.0	50	Void	Void	Void	180	8.0	61	360	3.0	62
15	240	9.0	58	330	6.0	51	Void	Void	Void	180	8.0	63	15	3.0	63
16	230	9.0	59	360	6.0	53	100	4.0	50	180	8.0	63	15	3.0	63
17	230	10.0	59	330	6.0	52	95	4.0	49	200	5.0	63	30	3.0	61
18	210	9.0	59	360	5.0	52	120	3.0	45	170	5.0	60	90	3.0	56
19	240	7.0	57	360	4.0	52	150	2.0	41	170	4.0	57	60	3.0	50
20	240	5.0	54	Calm	Calm	45	90	Calm	40	170	3.0	55	60	3.0	48
21	210	4.0	52	Calm	Calm	42	120	2.0	39	200	3.0	54	30	2.0	46
22	210	4.0	51	Calm	Calm	40	130	Calm	38	200	3.0	52	30	3.0	45
23	230	3.0	50	Calm	Calm	39	150	2.0	38	210	5.0	55	360	2.0	42
24	230	3.0	48	Calm	Calm	38	Calm	Calm	37	210	7.0	58	360	2.0	40

TABLE B-14. EPA METEOROLOGICAL DATA, SITE 3, DETROIT, MICHIGAN

Date	11/01/78			11/02/78			11/03/78			11/04/78			11/05/78		
Hour	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)	Wind Direction (°)	Wind Speed (mph)	Temperature (°F)
01	Calm	Calm	39	230	3.0	39	Calm	Calm	48	Calm	Calm	51	Calm	Calm	60
02	Calm	Calm	38	230	3.0	39	Calm	Calm	47	Calm	Calm	50	Calm	Calm	52
03	Calm	Calm	37	230	3.0	39	Calm	Calm	46	Calm	Calm	50	210	2.0	55
04	Calm	Calm	36	230	4.0	39	Calm	Calm	44	Calm	Calm	49	210	3.0	56
05	Void	Void	Void	230	4.0	39	Calm	Calm	42	Calm	Calm	49	210	4.0	57
06	Void	Void	Void	230	3.0	38	Calm	Calm	43	Calm	Calm	49	210	5.0	57
07	Void	Void	Void	230	3.0	38	Calm	Calm	43	Calm	Calm	48	210	5.0	56
08	Void	Void	Void	230	4.0	38	Calm	Calm	44	220	2.0	49	210	5.0	55
09	Void	Void	Void	230	4.0	41	Calm	Calm	50	220	3.0	51	210	7.0	58
10	Void	Void	Void	260	4.0	46	230	3.0	58	230	4.0	58	210	9.0	60
11	Void	Void	Void	260	4.0	53	220	4.0	63	240	5.0	66	210	8.0	65
12	Void	Void	Void	260	5.0	58	200	6.0	66	260	5.0	70	220	8.0	69
13	Void	Void	Void	270	6.0	63	200	5.0	68	260	5.0	72	210	10.0	71
14	Void	Void	Void	270	7.0	68	200	5.0	70	220	6.0	73	210	10.0	73
15	Void	Void	Void	260	7.0	68	170	5.0	70	220	5.0	73	180	9.0	72
16	Void	Void	Void	260	7.0	68	170	6.0	69	220	6.0	74	180	8.0	73
17	120	3.0	52	260	5.0	67	180	5.0	67	220	4.0	72	180	6.0	72
18	120	3.0	49	250	3.0	63	180	4.0	63	210	4.0	70	190	6.0	71
19	180	4.0	48	Calm	Calm	60	170	3.0	60	Calm	Calm	67	200	7.0	70
20	200	3.0	45	Calm	Calm	58	190	2.0	59	200	2.0	66	200	7.0	69
21	210	3.0	44	Calm	Calm	53	200	3.0	58	210	3.0	66	200	7.0	68
22	230	2.0	42	Calm	Calm	52	200	2.0	56	210	3.0	63	210	6.0	67
23	210	3.0	41	Calm	Calm	50	210	2.0	54	345	2.0	56	210	7.0	66
24	230	3.0	40	calm	Calm	49	210	2.0	54	Calm	Calm	51	210	6.0	65